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SUBTERRANEAN TELEMETRY DATA REDUCTION-MIGHTY EPIC.(U)
JUN 77 T A STOUGH

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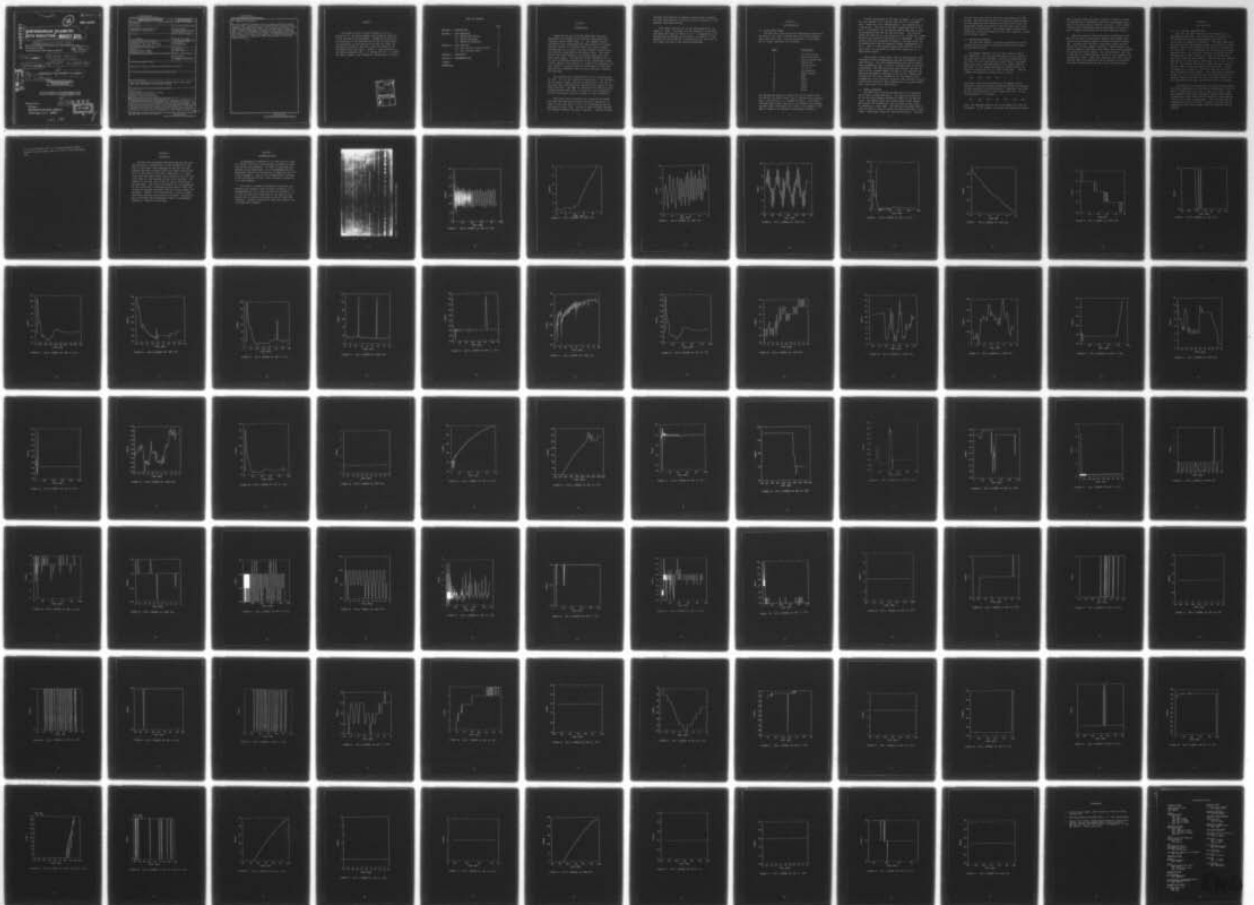
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**SUBTERRANEAN TELEMETRY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The ground motion data obtained across a geologic interface on MIGHTY EPIC Interface Experiment were converted to digital for- mat and stored in three hardened canisters deep underground. The data were retrieved after the test by transmitting a coded signal through the earth that caused a particular canister to transmit stored digital data to a receiver on the surface where they were recorded as serial digital information. This report discusses		

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20. ABSTRACT (Continued)

the data reduction technique used to produce graphical output from the tape, presents all of the data as plots and notes the anomalies in system performance. One canister was found to have stored ground motion data, the other two had stored no motion data. A later interrogation showed that the memory units had been reset. The reason is not known. Recommendations are made for 1) recovery of one of the canisters to ascertain the cause of rewriting and 2) a change in output data format to make data analysis easier.

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PREFACE

The author wishes to express thanks to Dr. R. A. Shunk for his continuing support and technical expertise in the writing of this document. Thanks are also due to the personnel in the ADD Division of the Air Force Weapons Laboratory at Kirtland Air Force Base for their immediate and attentive reaction to the A/D reduction of the MIGHTY EPIC data tapes. Thanks is also expressed to the Develco Engineers Mr. L. H. Rorden and Mr. T. C. Moore for their comments and informative remarks about the data.

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SECTION 1

INTRODUCTION

Ground motion data from the MIGHTY EPIC Interface Experiment was recorded by the Develco Underground Data Telemetry System (UDTS) (Ref. 1). The signals from 36 transducers were conditioned and then converted to digital form and stored in 3 separate UDTS's for later wireless transmission to a receiver and tape recorder located above the Interface Experiment on the Rainier Mesa. The transducers were accelerometers, DX velocity gages and ytterbium stress gages. The data from these transducers was to be used to determine differences in the ground motion when a hard competent rock underlies a softer less competent rock. This report is concerned with the performance of the UDTS and with the techniques used to recover the data transmitted from them.

The canisters are labeled CAN A, B, or C representing the 210', 300' or 400' canisters respectively. The distances are horizontal ranges from the working point to the top of the drill hole down which the canisters were lowered to their final positions. The UDTS was fielded by the Waterways Experiment Station (WES) (Ref. 2) which was also responsible for the electronics from the recorder to the transducers.

There were three occasions after execution of MIGHTY EPIC when the data were retrieved from the canisters; the night of the event May 15, 1976, the following day May 16, and again in June, 1976. The May 15 data included segments of selected channels from the 3 canisters. The May 16 data

included only portions of channels from the 400' canister. The June interrogation consisted of short sections of a few channels from each canister.

This report presents all of the data graphically in counts vs. time. The graphs are all marked as to the data read date and either as CAN A, B or C. A comparison of interrogations by channel and canister is presented. A few theories are discussed but no conclusions are set forth in this report for any of the observed phenomena.

SECTION 2
DATA REDUCTION

2.1 ANÁLOG TAPE FORMAT

The UDS data received by Electromechanical Systems of New Mexico, Inc. (ESI) from WES were on 14 track magnetic tapes which were dubs of the original WES 32 track tapes. The 14 tracks contained the following:

<u>TRACK</u>	<u>DESCRIPTION</u>
1	BIT Clock Pulses
2	BYTE Clock Pulses
3	Serial Digital Data
4	Analog Data
5	"Parity Error"
6	"0" or "1"
7	Wide Band RF
8	Narrow Band RF
9	NFRE
10	Blank
11	Voice
12	IRIG C
13	Blank
14	Blank

The information needed to remove the Serial Digital Data are the BIT and BYTE clocks, IRIG C, and the Serial Digital Data. Each record (i.e. a number of blocks - each block contains eight words) consists of two channels of alternating data points referred to as A and B. An example of the data is shown as an expanded oscillograph in Figure 1.

A brief description of the data in Figure 1 is in order. The line labeled "1" is the BIT sync and "2" is the BYTE sync. There are 9 bits between bytes. The leftmost bit is a parity bit. The next is the most significant bit of the word. Line number 3 is the Serial Digital Data and is used in conjunction with the bit and byte syncs. For each bit either the data bit is set or not set (i.e. either up or down). The bits are tallied in the normal 2's complement. As mentioned earlier and indicated in Figure 1, the data words are alternating and from two separate channels designated as A or B. Line 4 is the analog signal level which is the voltage from a D/A converter for each byte; again this is a multiplexed signal.

Each record of data begins with an identification code followed by three housekeeping words which immediately precede the data. The three housekeeping words contain additional information that is used as a double check on the data transmitted. The identification code includes the CAN address and the channel number followed by the beginning and ending block numbers contained in the record. During data retrieval at NTS, this information was set manually and transmitted to the canisters as part of the code that started a particular canister's data transmission of a given channel and a particular set of data blocks.

2.2 ANALOG TECHNIQUE

The UDTS data received from WES were on 14 track magnetic tapes as mentioned above. The tapes were digitized at the Air Force Weapons Laboratory (AFWL) by the ADD Division. The analog track and serial digital track signals were pulled off separately so the D/A digital data could be checked at a later date. The ADD Division dubbed IRIG B onto the tape in order to better interface with their system setup. The analog signal was digitized directly. The digi-

tal data were processed by the Pulse Code Modulation (PCM) system. The PCM system handles non-standard formatted data. The PCM method was more accurate and more useful since the analog data lacked calibration files therefore true levels could not be established. The analog signals however were useful on a first-look comparison basis and served as a check for verifying results.

2.3 REDUCTION TECHNIQUE

The CDC 6600 computer at Sandia Laboratories in Albuquerque (SLA) was used to reduce the PCM processed tapes to listings and plots.

The graphs (Figures 2-77) all have counts as the Y axis amplitude. The A/D converter had an 11 bit capacity, but only 8 bits were recorded. The Develco System was set up with 9 bits for each data word (one "parity" and eight data bits), thus a maximum value of 255 counts could be recorded. If the counts continued to increase after 255 then the system recycled to 0 and started over. That is, suppose the sequence of points was as follows:

232 239 254 255 5 2 8.

This means that after recording 255 the numbers should continue to increase because ground motion data are assumed to have continuous first derivatives. Therefore, the count did not dip back down to 5 but actually was 261. The revised sequence is as follows:

232 239 254 255 261 258 264.

Thus, the computer code was set up to handle this type of situation. In the graphs, all points are adjusted as noted

above and only large one point "spikes" of double or greater magnitude were eliminated since these represented some type of bit error and are probably not data. These "spikes" occurred very infrequently and are mentioned here only to give a complete discussion of the data reduction process.

When the canisters were initially interrogated at the NTS, in all cases, a particular canister and channel were called up and a preset number of blocks of data was pulled off. In nearly all instances, the entire signal was not pulled off but only segments (blocks). Where possible during the computer reduction, these blocks were pieced together to display the entire signal. On a few occasions, the loss of one word in a block caused a switch in A & B channels for a particular signal. When this occurred, that exact spot in the data had to be identified and an average of the preceding and following points was put in for that lost point.

SECTION 3

DATA ANALYSIS

3.1 210' AND 400' CANISTER DATA

The 210' and 400' canisters did not produce any meaningful motion data. The signals were, in most cases, not related to any known experimental occurrences as can be seen in Figures 34 through 77. The data taken from the same canister and channel on May 15 and 16 and in June, however, tend to have different data levels and signatures in a few cases. This phenomenon was discussed with Develco engineers but it is not clear just what could have caused retriggering of these canisters on May 16 and again between May 16 and the June readout. Some of the data remained the same as is indicated in the Figures 48, 49, 50, 51, 56, and 58. The obvious conclusion is that the data was written over one or more times during those periods. Looking at Figure 65, it seems as if data of some sort may have been recorded for this channel. This represents data taken on May 16. It is unfortunate that this portion was not recorded on May 15 also but only up to 90 msec (Figure 64) was recorded on that date and the data are not coincident.

All the data is included here no matter how few points and each graph labeled as to which interrogation of the canister it represents (i.e. May 15, May 16 or June). The data channel plots are in ascending channel order number. A comparison of the data from the different interrogation dates can be easily accomplished. Since no real data was recorded on the 210' and 400' canisters, all that can be compared are the level changes from the separate interrogations.

As mentioned earlier, the blocks of data were pieced together where possible. Figures 68 and 69 each represent segments read on May 15 and May 16 and were pieced together as indicated. This is interesting and informative since from one day to the next the data were consistent, in this one case, indicating no "retriggering" here.

An interesting phenomenon occurred on Channel 6A CAN C (Figure 70). There seems to be the tail end of a signal beginning about 550 msec even though no data were recorded earlier in time (Figures 71, 72). This record remained in the canister and was interrogated again in June giving the exact same data as indicated in Figure 73.

3.2 300' CANISTER DATA

This canister provided believable data as can be seen in Figures 2, 6, 20, 12, 14, 16, 18, 22, 26, 28, 30 and 32. Channel 1A was the only channel that was lost. There is a limited effort at this time to attempt to recover this channel by Fourier Analysis techniques. The signals are not only believable but with the engineering units used for the respective traces, the signals become reliable ground motion indicators. The horizontal velocity traces (Figures 6, 14, 28) have the same signatures. Similar structure is seen upon comparison of the vertical velocity traces (Figures 12, 18). The signals in Figures 16 and 32 are also comparable as acceleration time histories and Figures 22, 26 and 30 are typical stress signals. All the signals are distinct and accurate representations of their particular functions. The 300' canister data, therefore, give clear evidence of the successful operation of the UDTs.

All June interrogations produced different data (in most cases different levels) than the May 15 interrogation.

Unfortunately no 300' data were read out on May 16. This may have provided some clue as to what occurred later.

The June interrogations of Channel 1A and 1B (Figures 3, 4, 5, 7, 8, 9) bear no resemblance to the May 15 data. Note in particular, Figures 3 and 4. These data were taken on the same day but Figure 4 which includes data from 32 msec to about 51 msec is entirely different from Figure 3 in the same time interval. There is, however, a structure resemblance in Figure 4 to that in Figure 2 (May 15 read) but the levels do not coincide. Similarly, the situation occurs on Channel 1B (Figures 7,8). Verification of the oscillograph identification code confirms the fact that these records represent Channel 1 of the 300' canister. The above mentioned phenomenon also is seen in Figures 19, 21, 23 and 25 for Channel 4A and 4B.

Special attention is called to Channel 6A (Figures 30 and 31). These were both taken on May 15, however Figure 31 is not a reproducible trace of Figure 30 starting at about 700 msec out to 1 sec. This phenomenon is a mystery to Develco engineers as well as to this author. Note, however, the tail end of Figure 31. On this particular interrogation the recorder was programmed to read out to 142 blocks (the maximum limit was only 125 blocks). This was discussed with Develco engineers who believe that the system was probably just reading random locations and producing nonsense.

Comparing Channel 6A CAN B (Figure 31) with Channel 6A CAN C (Figure 70) shows identical signals. When this was first noticed by the author, a check was immediately made on the identification codes on the oscillographs for these two records and it was found that they are correctly labeled. There is no clear explanation for this occurrence at this time.

It is very possible this is a system generated signal related to power supply turn on or off in the instrumentation.

SECTION 4

CONCLUSION

Canister 300 responded beautifully during the event and the data do indeed attest to the capability of the UDTs in the field. What happened to the 200' and 400' channels and why different levels and traces were recorded at a later date is not fully understood. It is possible that the signal cables were severed to the 200' canister early in time causing no data to be recorded. The readout of the 300' data on May 15 and in June are not the same data. This could be explained by a retriggering of the system with a subsequent acquisition of data consisting of available voltages from the various signal conditioners. However, more information is clearly needed before any concrete conclusions can be made. Recovery of one of the UDTs would undoubtedly enable a knowledgeable engineer to identify the problem.

SECTION 5

RECOMMENDATIONS

As mentioned in subsection 2.3, the loss of a word in a block of data can occur causing a problem in reduction of the data channels. In order to alleviate this problem in any future data, it is recommended that the upper-most "parity" bit be used as an identifier for the A and B channels. This can be accomplished by setting or not setting the bit for A and B channels respectively in the hardware.

To be able to answer the questions raised by the detailed data analysis from the three canisters, it is recommended that one of the canisters be recovered. It is very possible that inspection of the canister will explain why no data were recorded on the 210' and 400' canisters. Recovery should also shed some light on the "retriggering" problems.

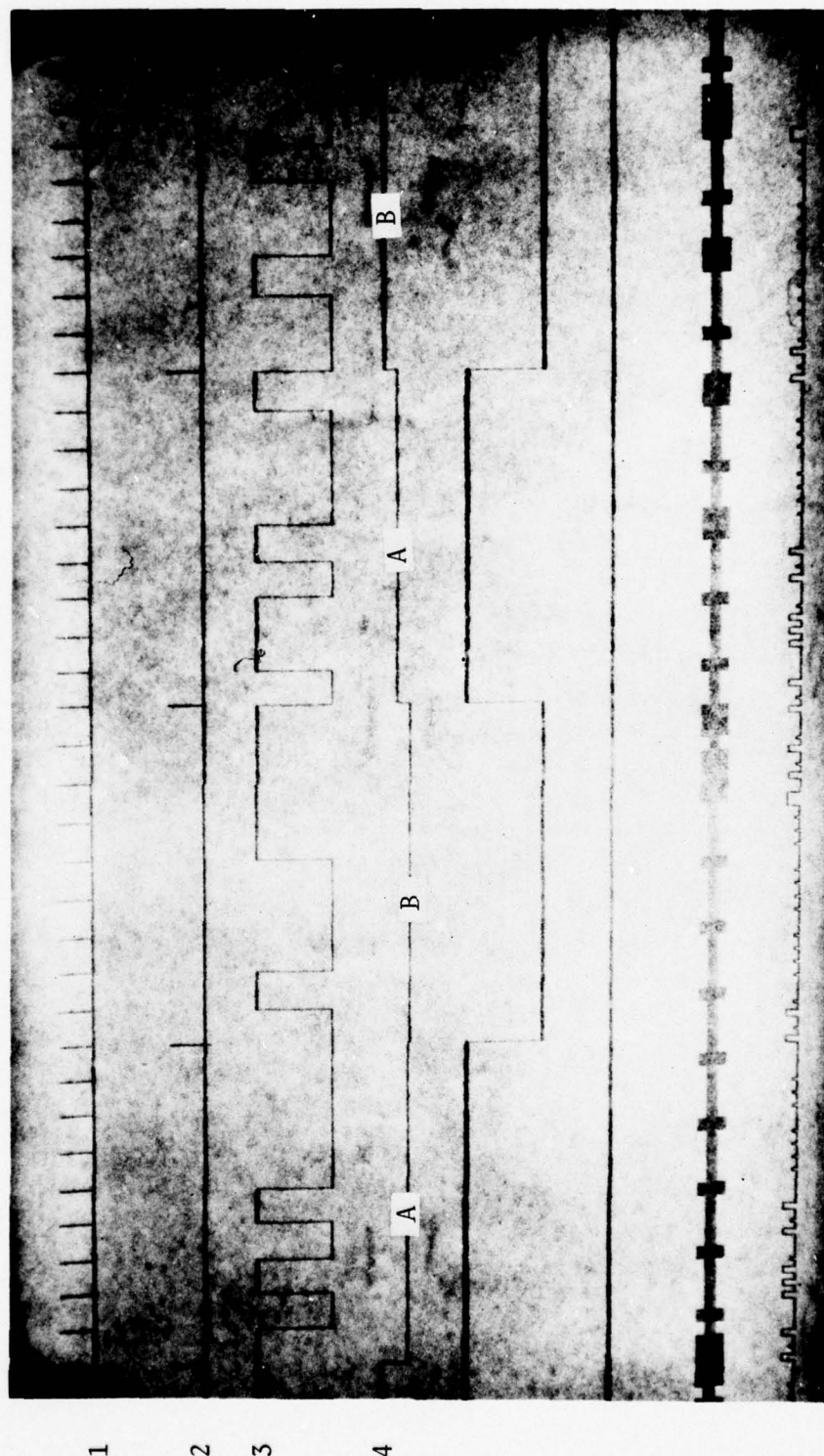


FIGURE 1. OSCILLOGRAPH OF MIGHTY EPIC TAPE FORMAT

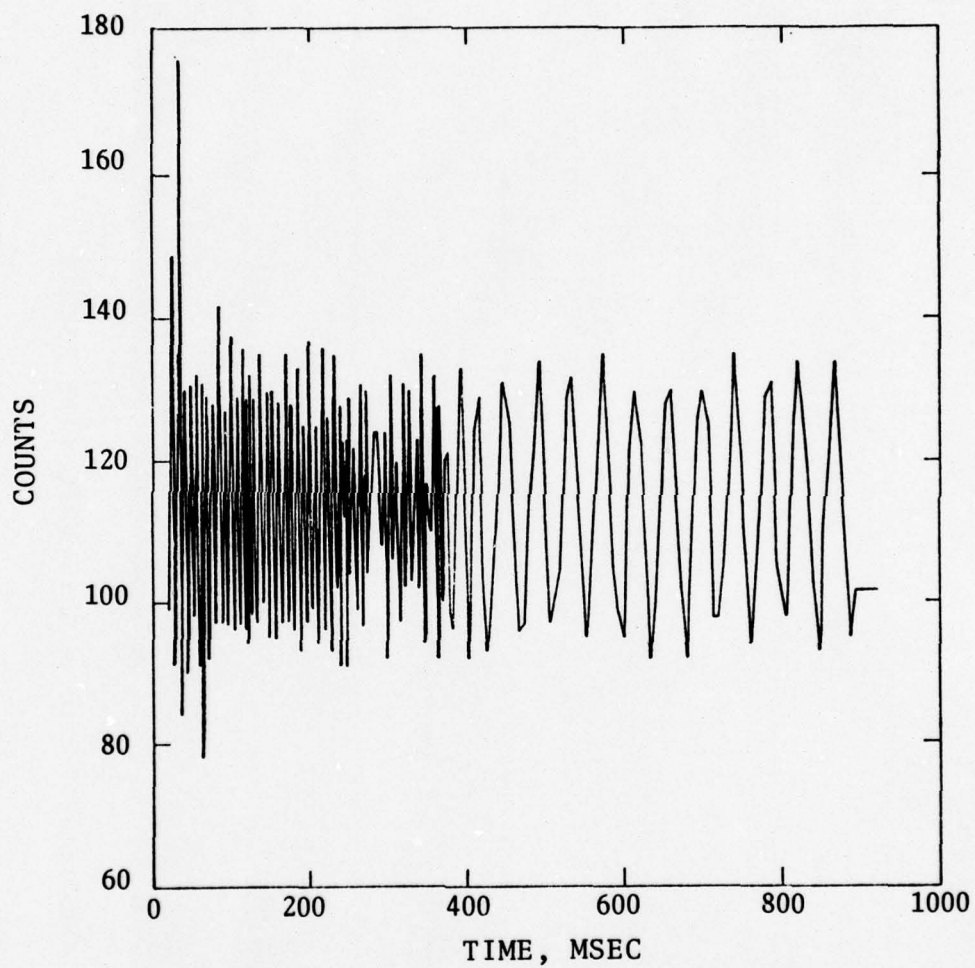


FIGURE 2. CAN B, CHANNEL 1A, MAY 15, 1976

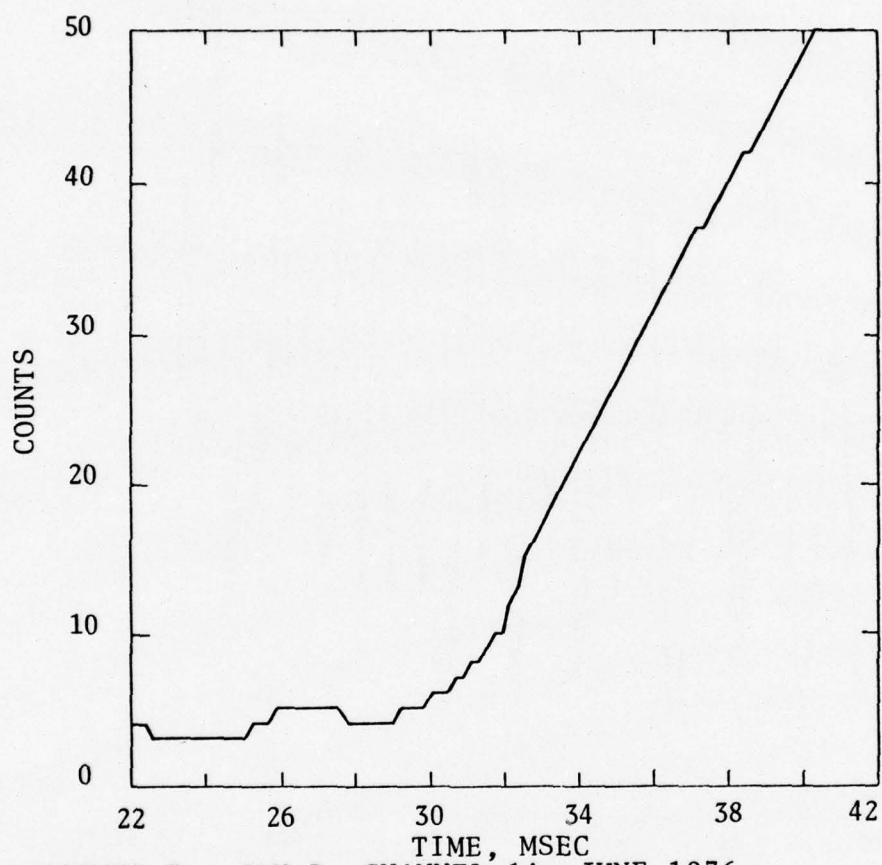


FIGURE 3. CAN B, CHANNEL 1A, JUNE 1976

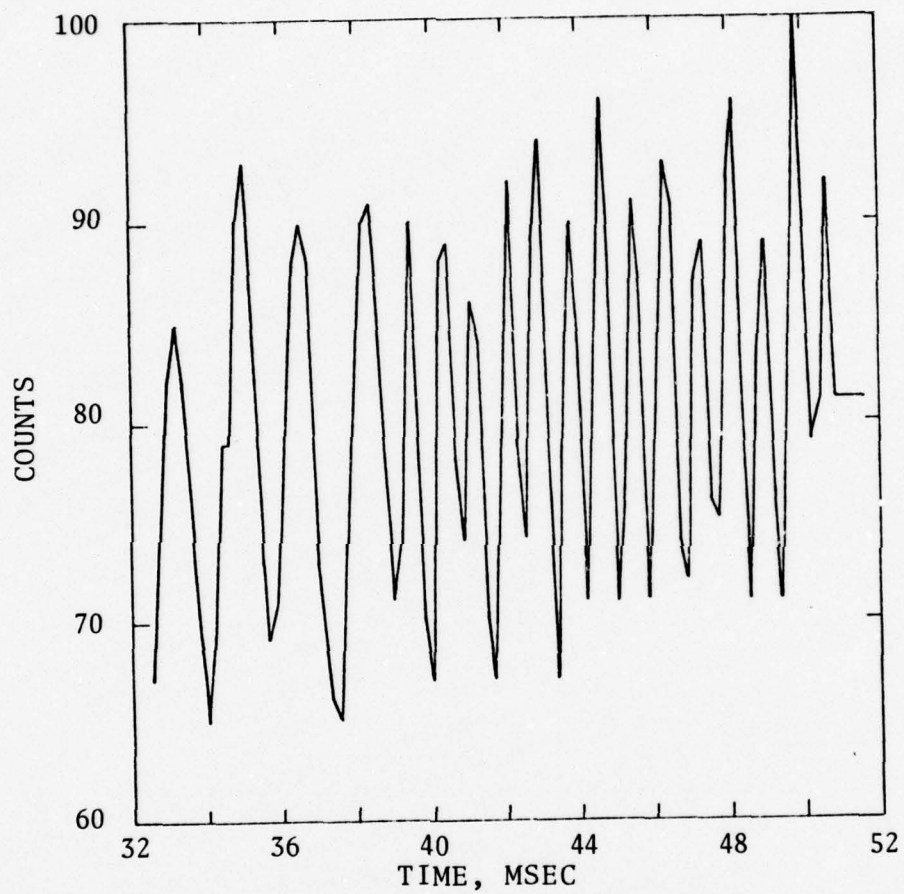


FIGURE 4. CAN B, CHANNEL 1A, JUNE 1976

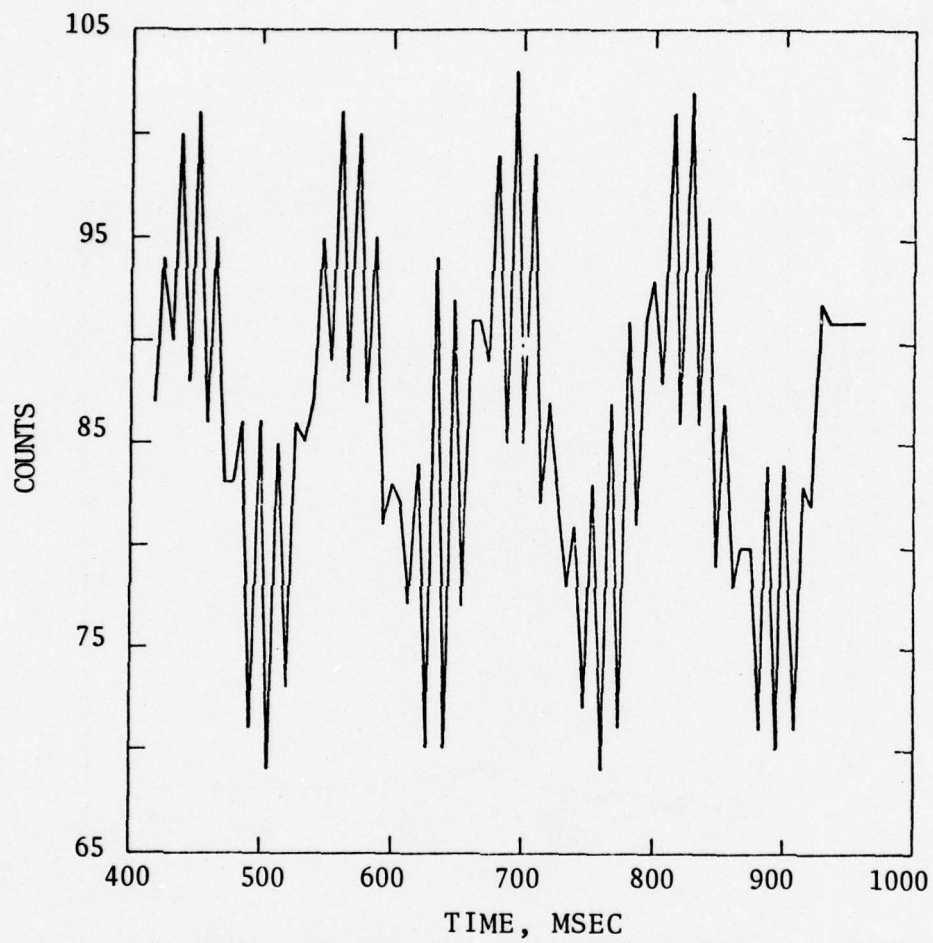


FIGURE 5. CAN B, CHANNEL 1A, JUNE 1976

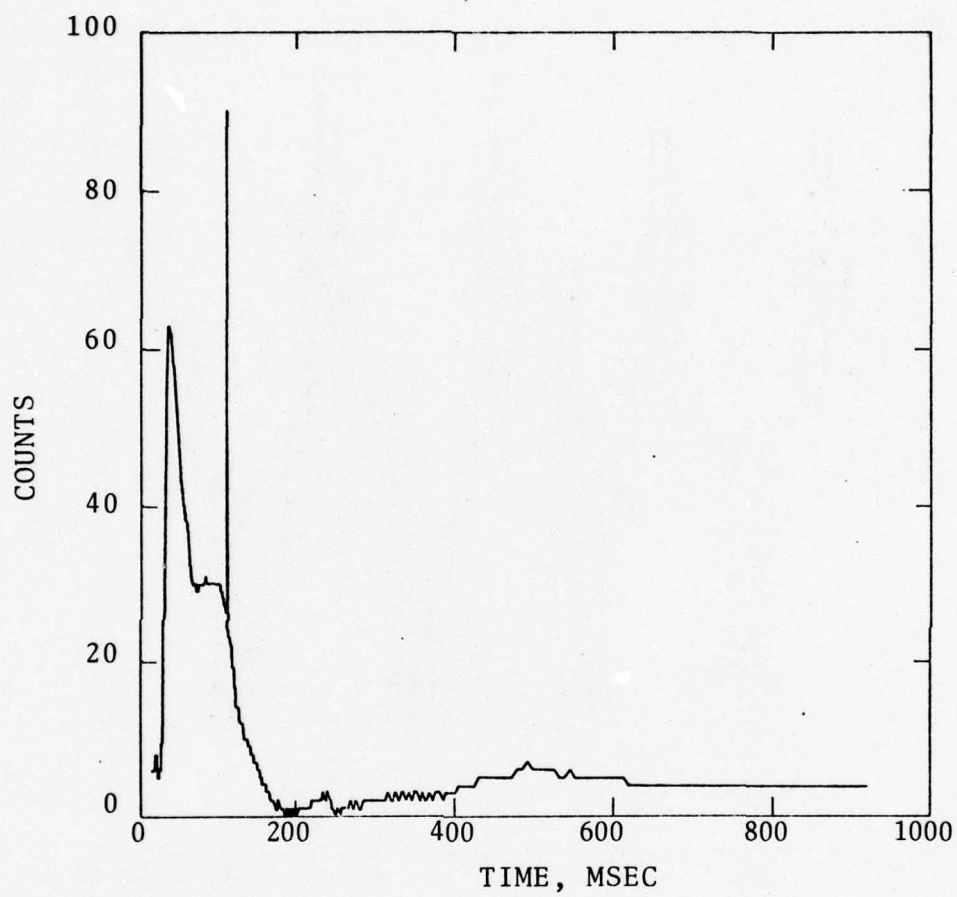


FIGURE 6. CAN B, CHANNEL 1B, MAY 15, 1976

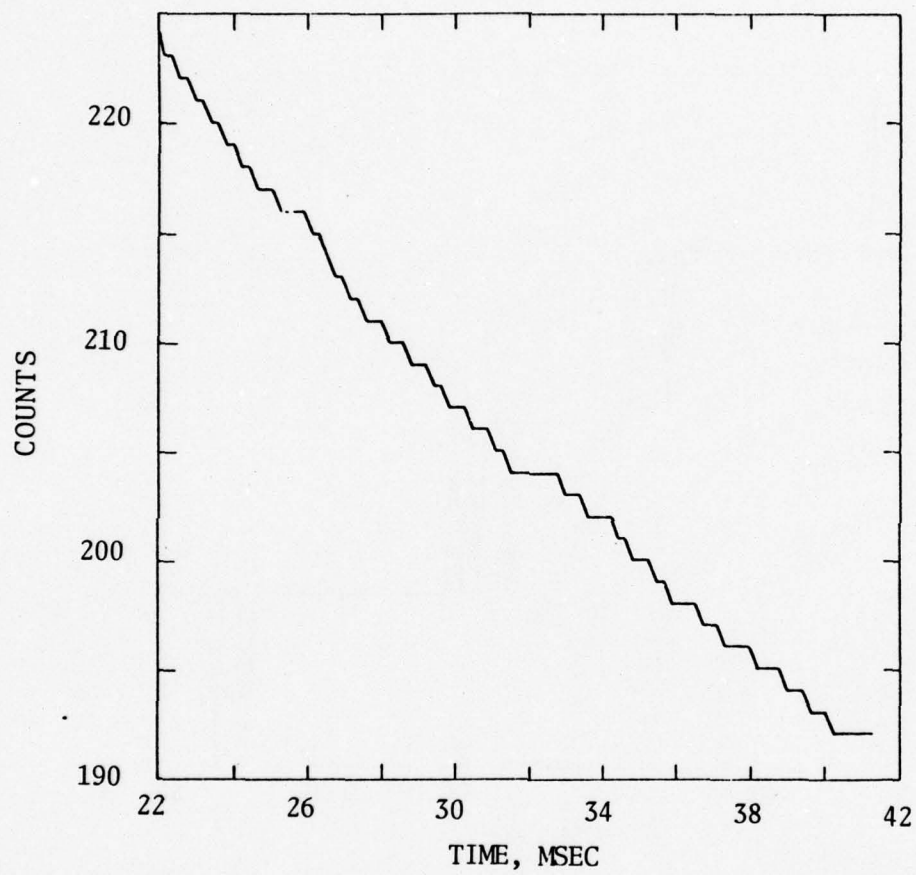


FIGURE 7. CAN B, CHANNEL 1B, JUNE 1976

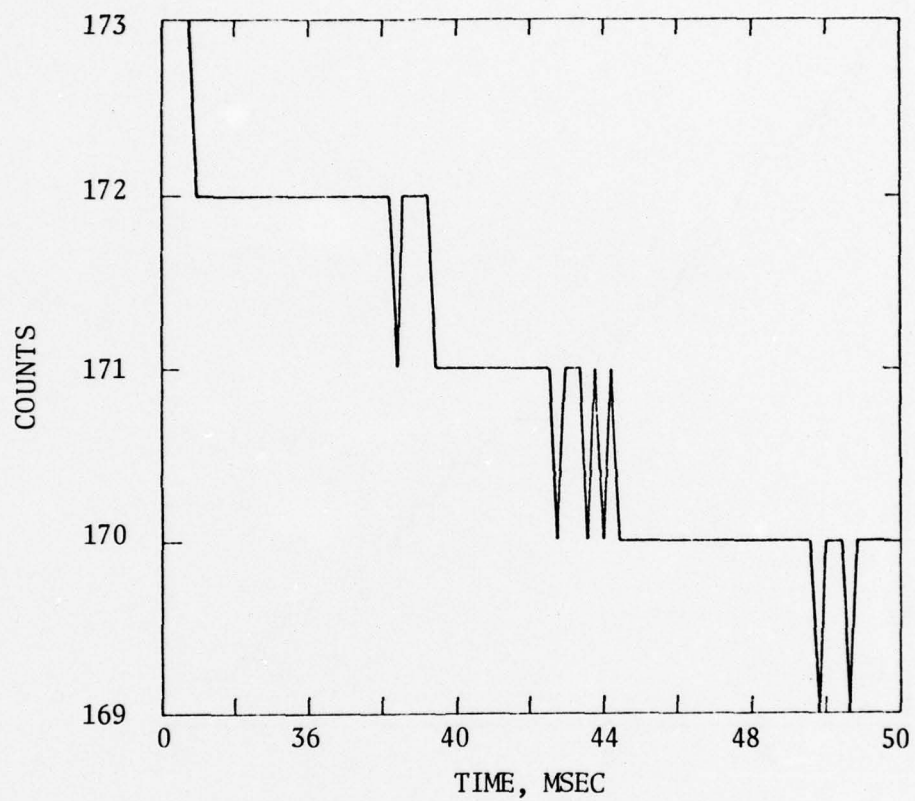


FIGURE 8. CAN B, CHANNEL 1B, JUNE 1976

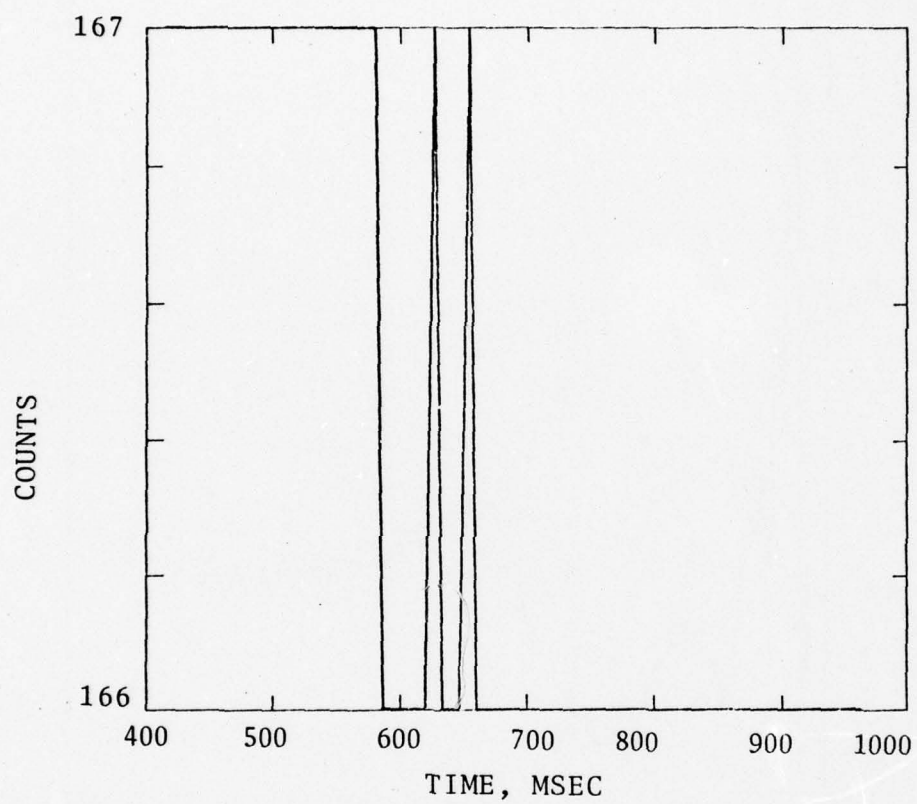


FIGURE 9. CAN B, CHANNEL 1B, JUNE 1976

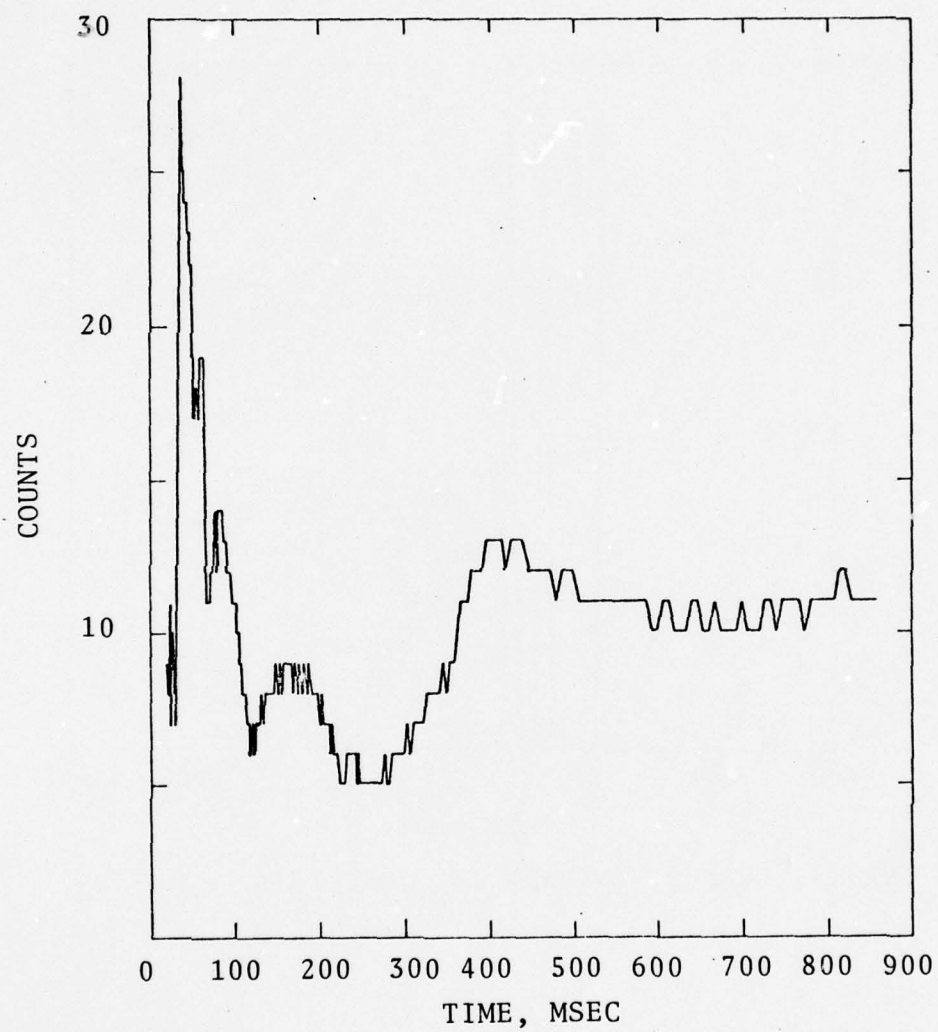


FIGURE 10. CAN B, CHANNEL 2A, MAY 15, 1976

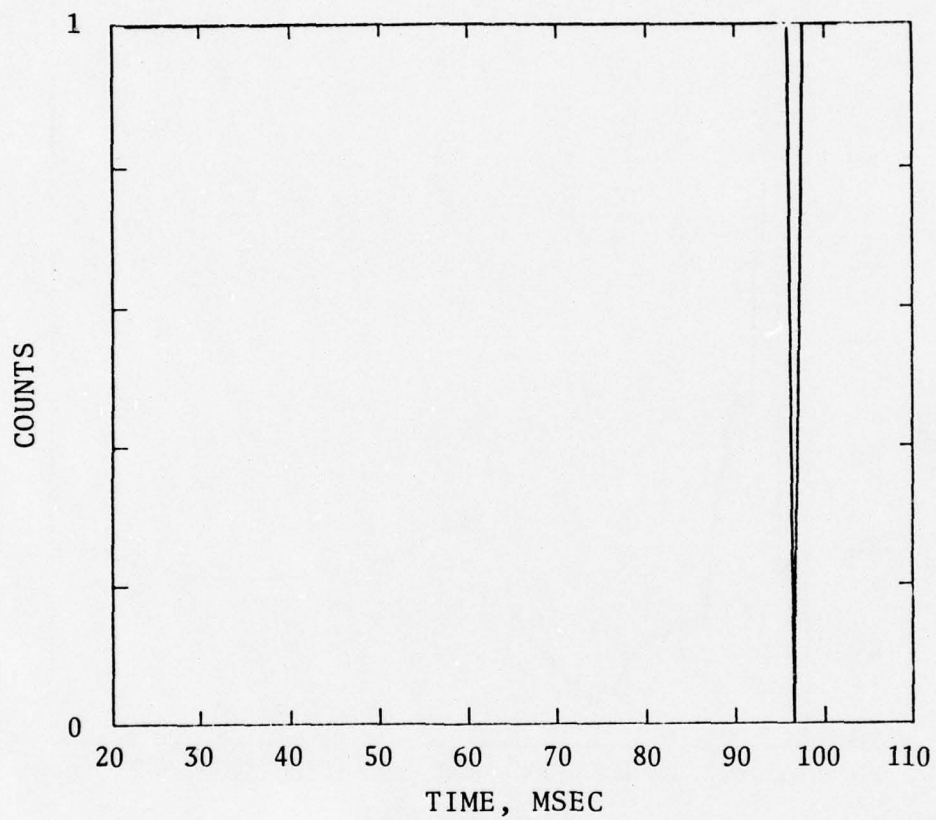


FIGURE 11. CAN B, CHANNEL 2A, JUNE 1976

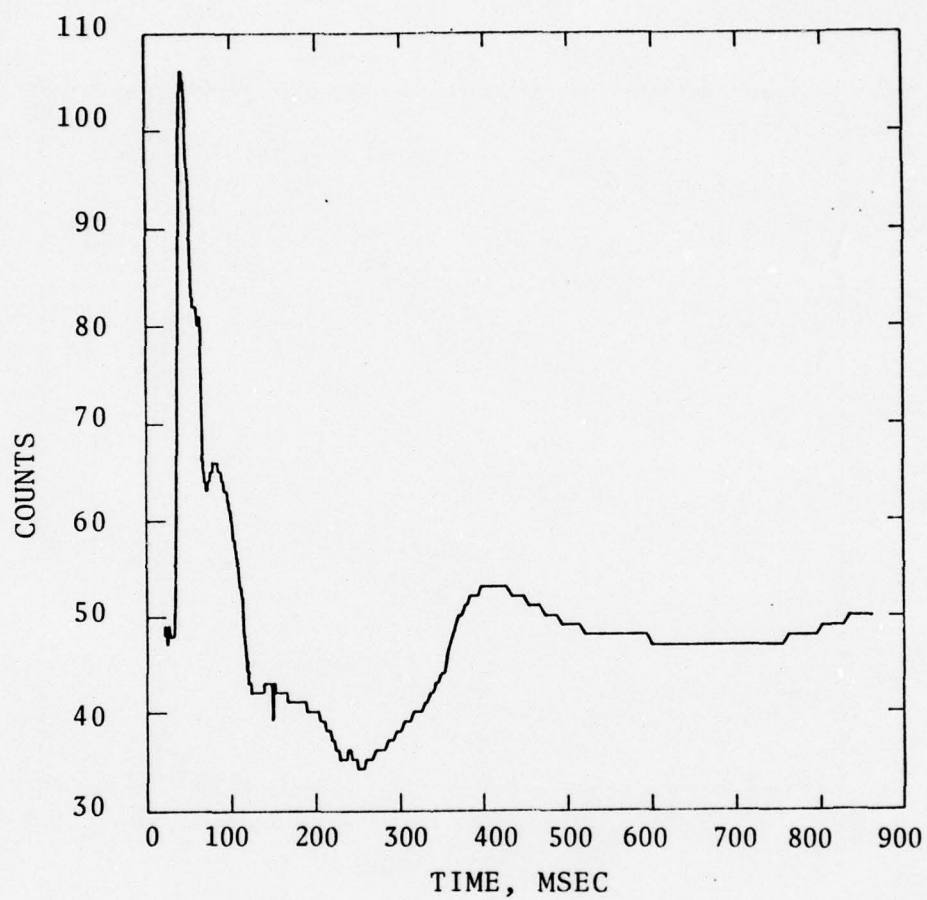


FIGURE 12. CAN B, CHANNEL 2B, MAY 15, 1976

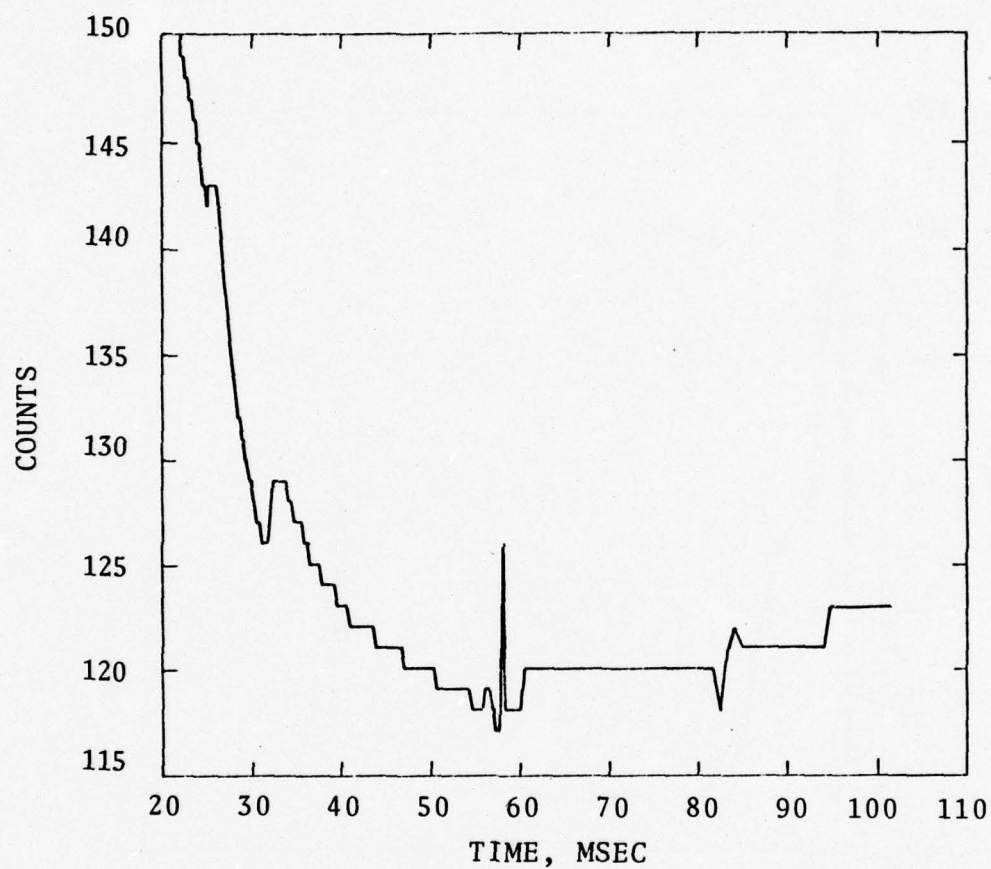


FIGURE 13. CAN B, CHANNEL 2B, JUNE 1976

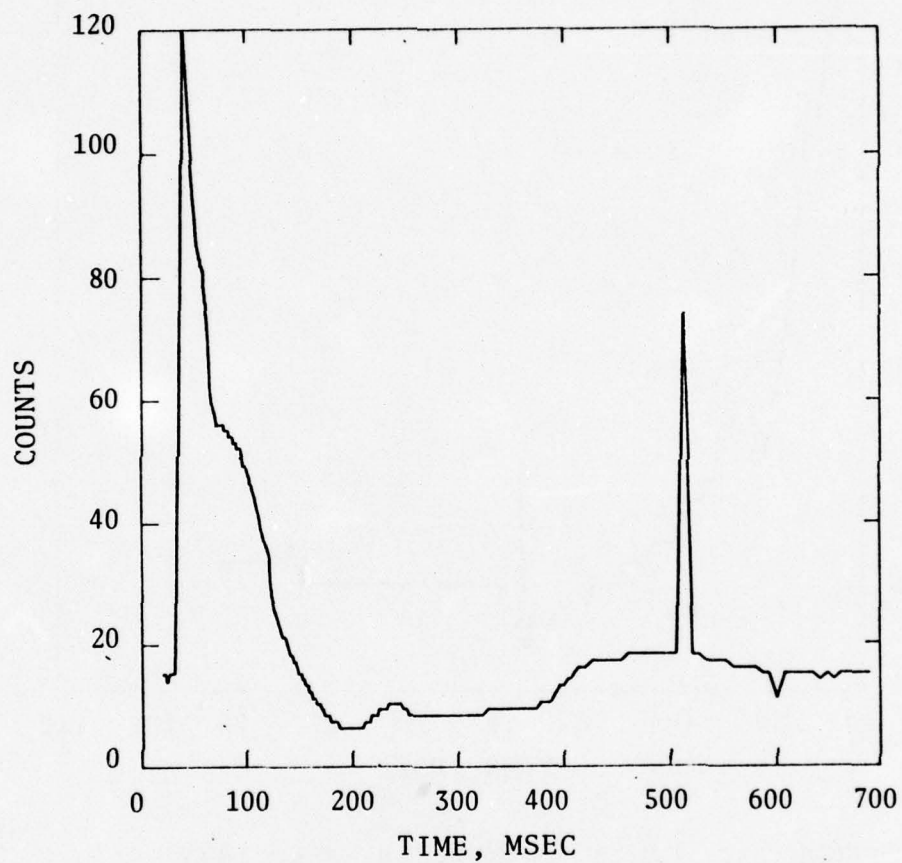


FIGURE 14. CAN B, CHANNEL 3A, MAY 15, 1976

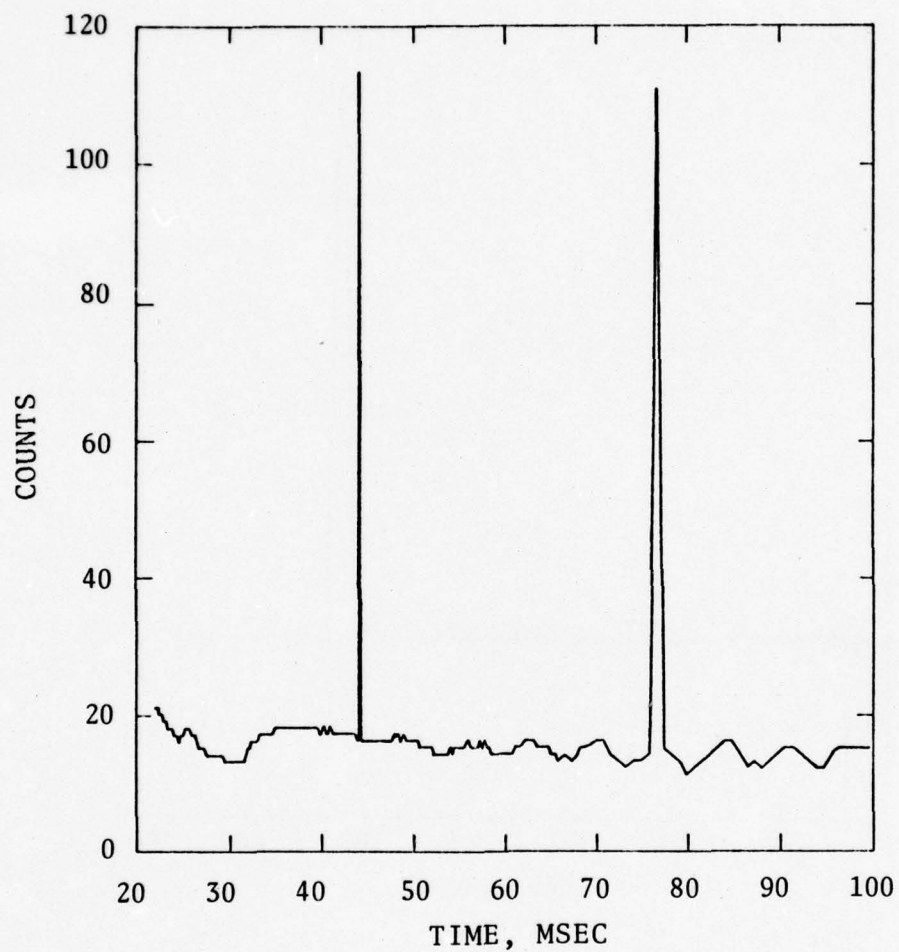


FIGURE 15. CAN B, CHANNEL 3A, JUNE 1976

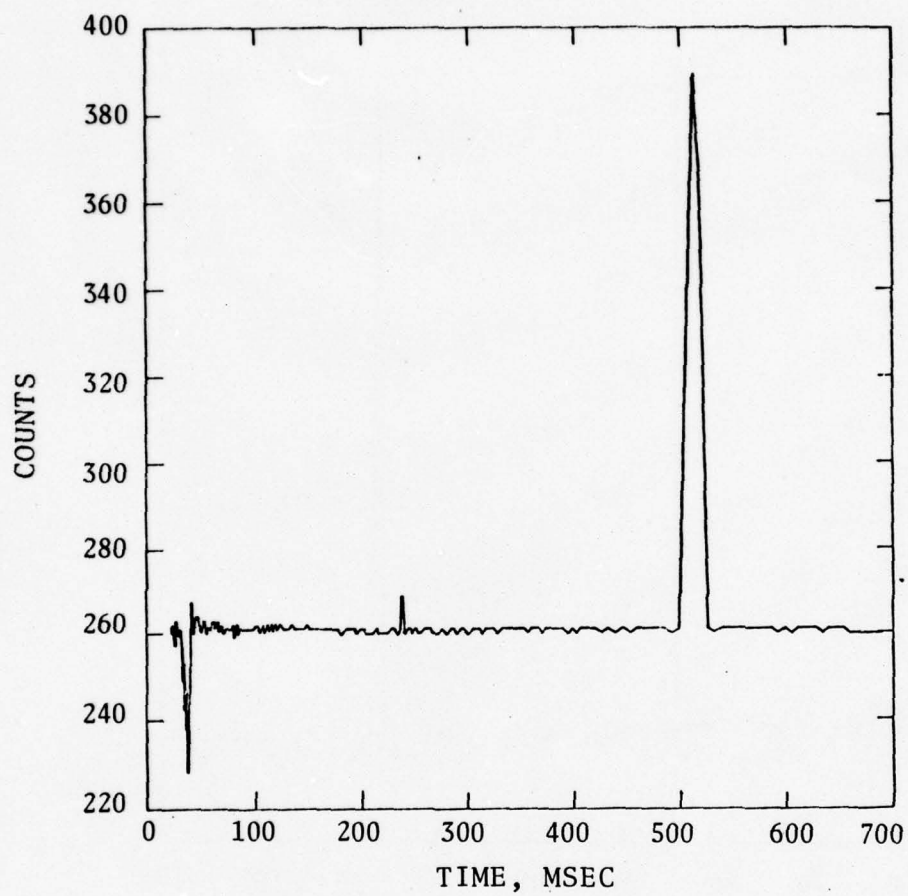


FIGURE 16. CAN B, CHANNEL 3B, MAY 15, 1976

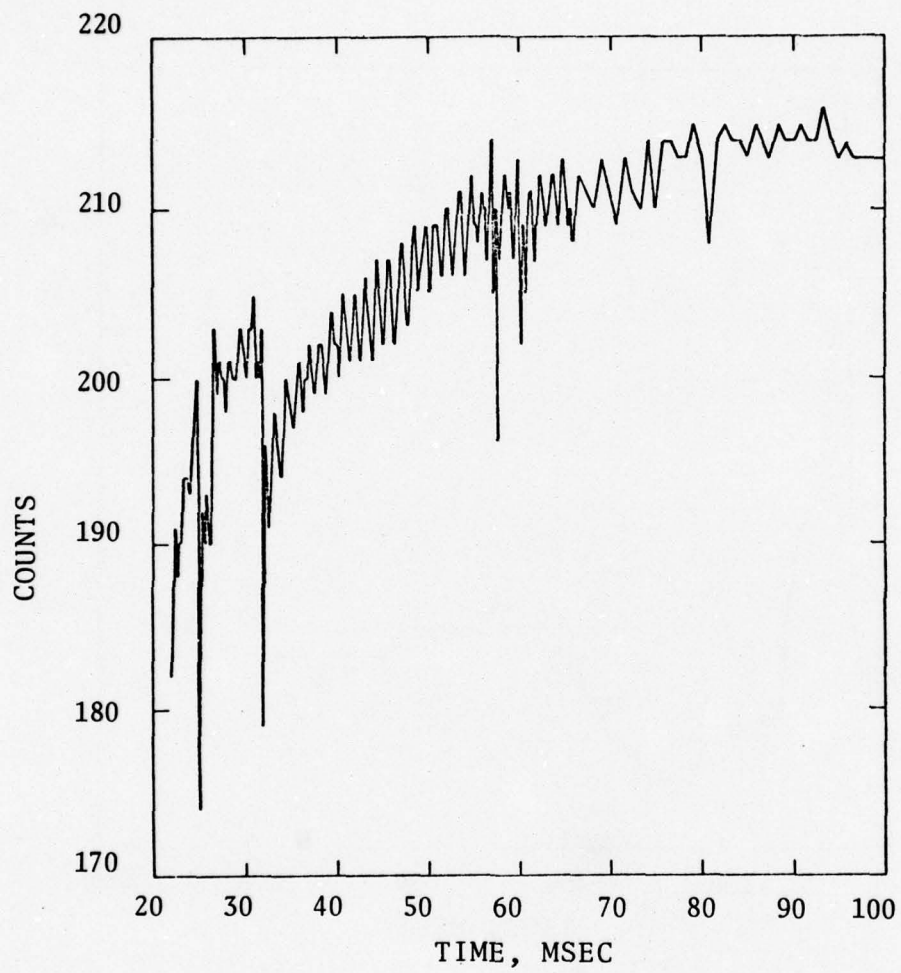


FIGURE 17. CAN B, CHANNEL 3B, JUNE 1976

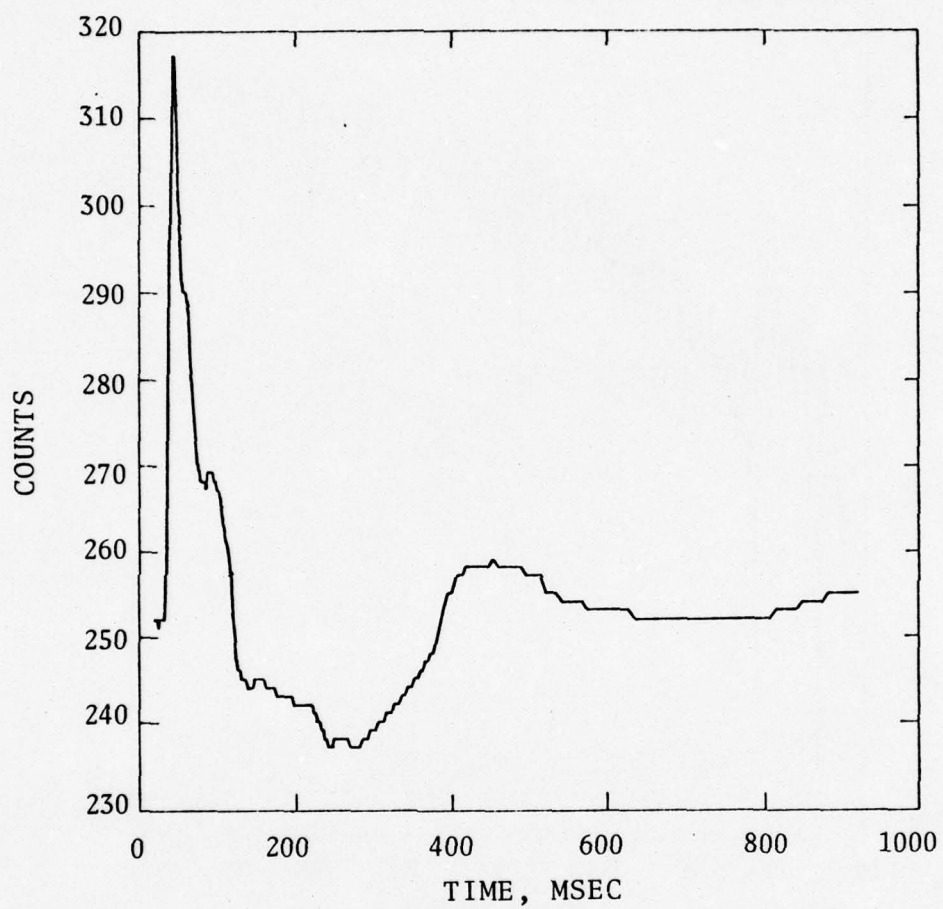


FIGURE 18. CAN B, CHANNEL 4A, MAY 15, 1976

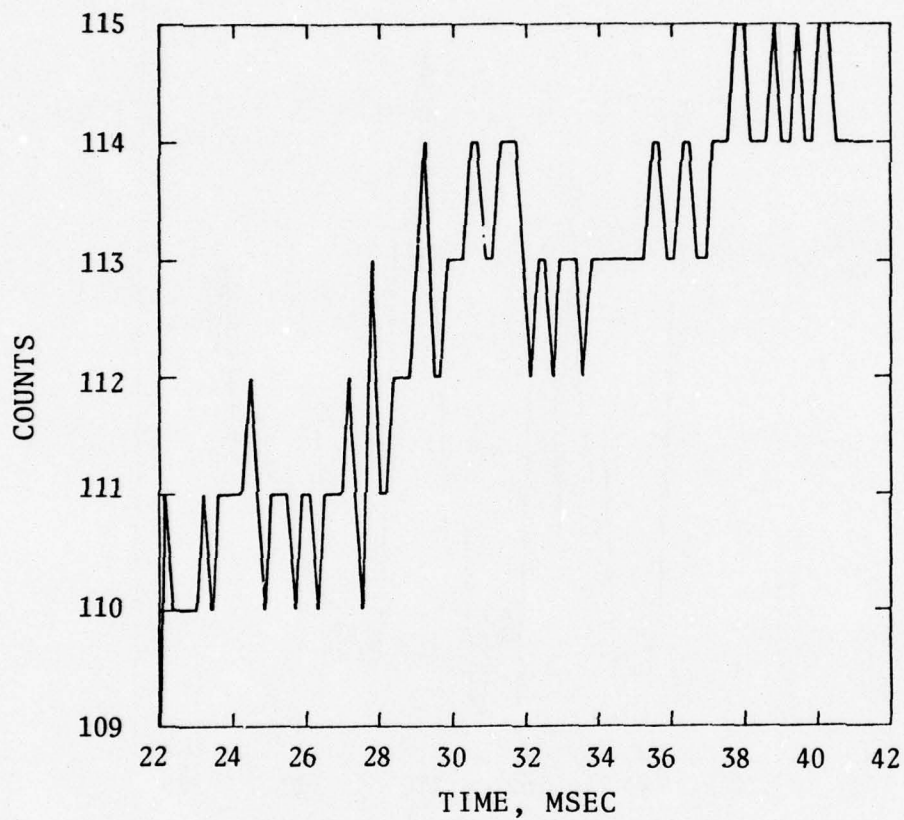


FIGURE 19. CAN B, CHANNEL 4A, JUNE 1976

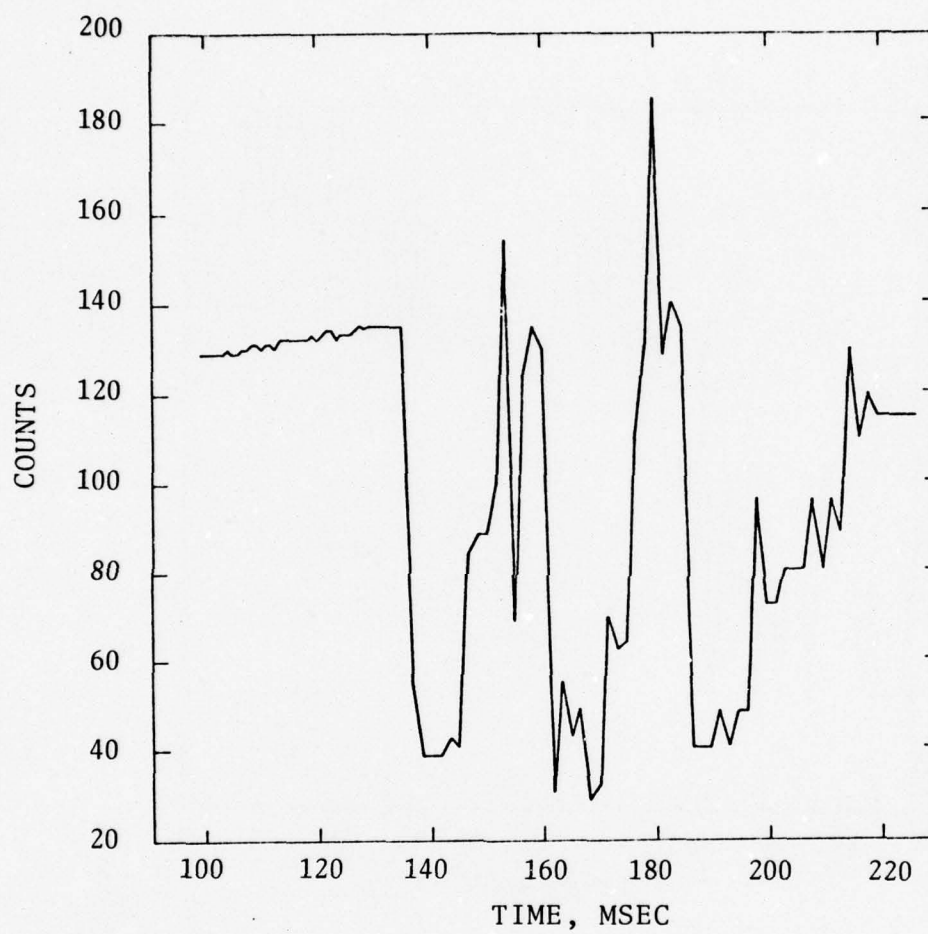


FIGURE 20. CAN B, CHANNEL 4A, JUNE 1976

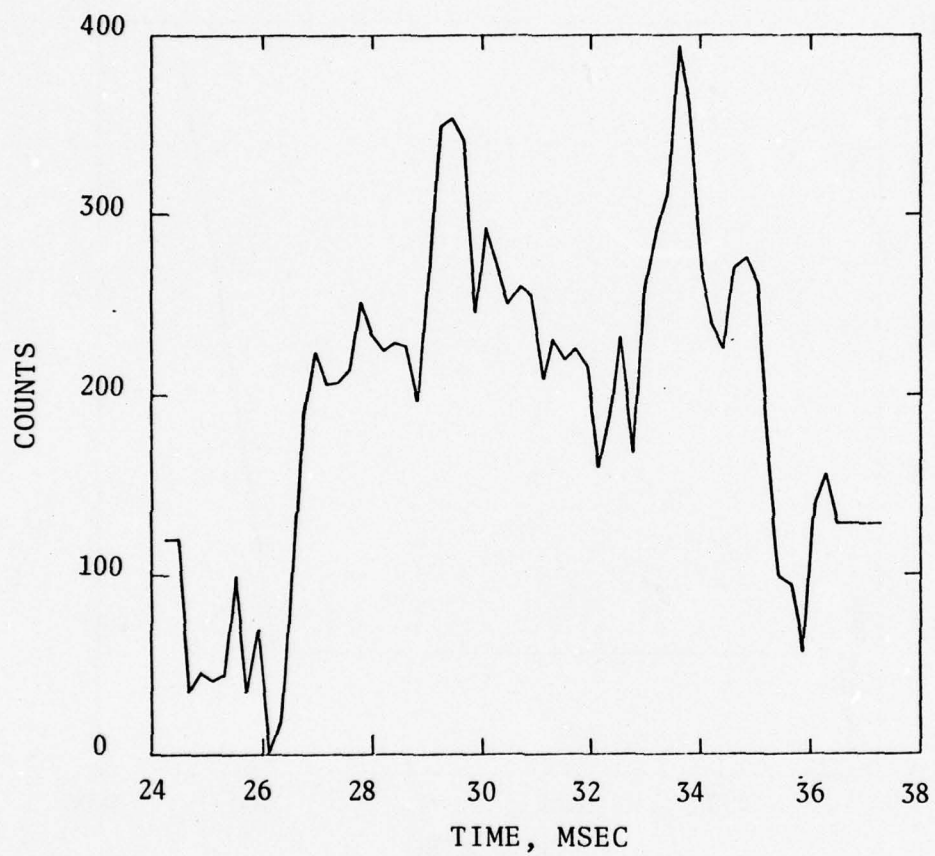


FIGURE 21. CAN B, CHANNEL 4A, JUNE 1976

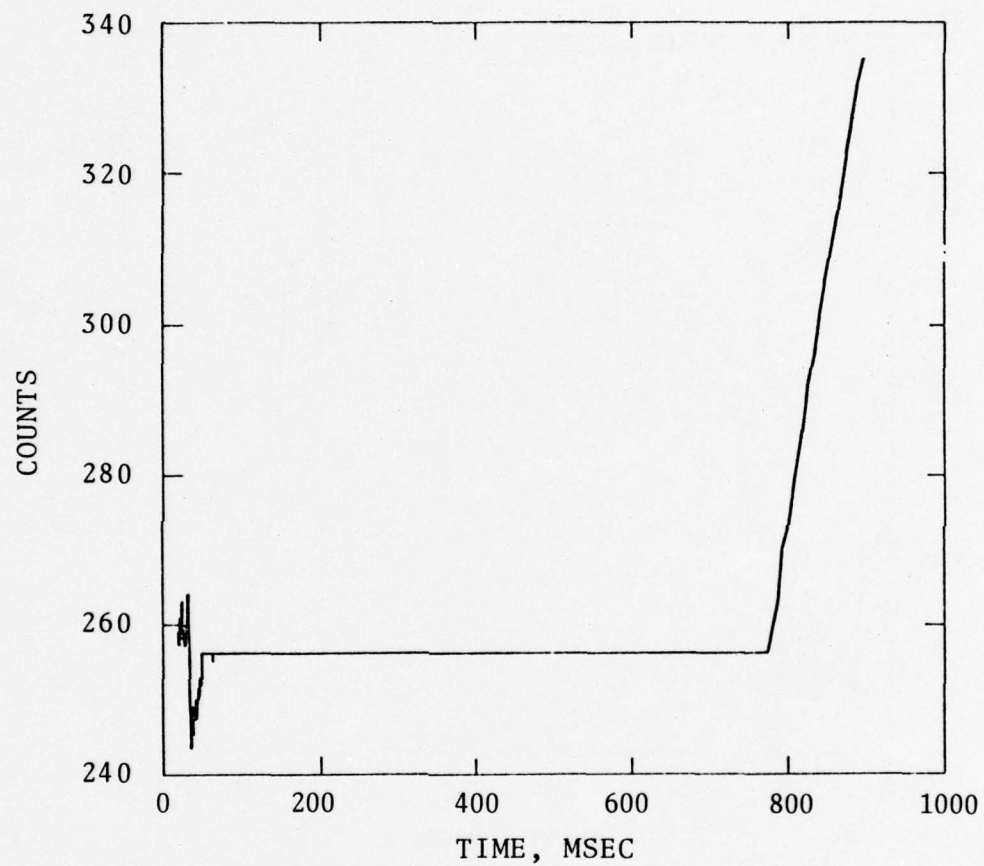


FIGURE 22. CAN B, CHANNEL 4B, MAY 15, 1976

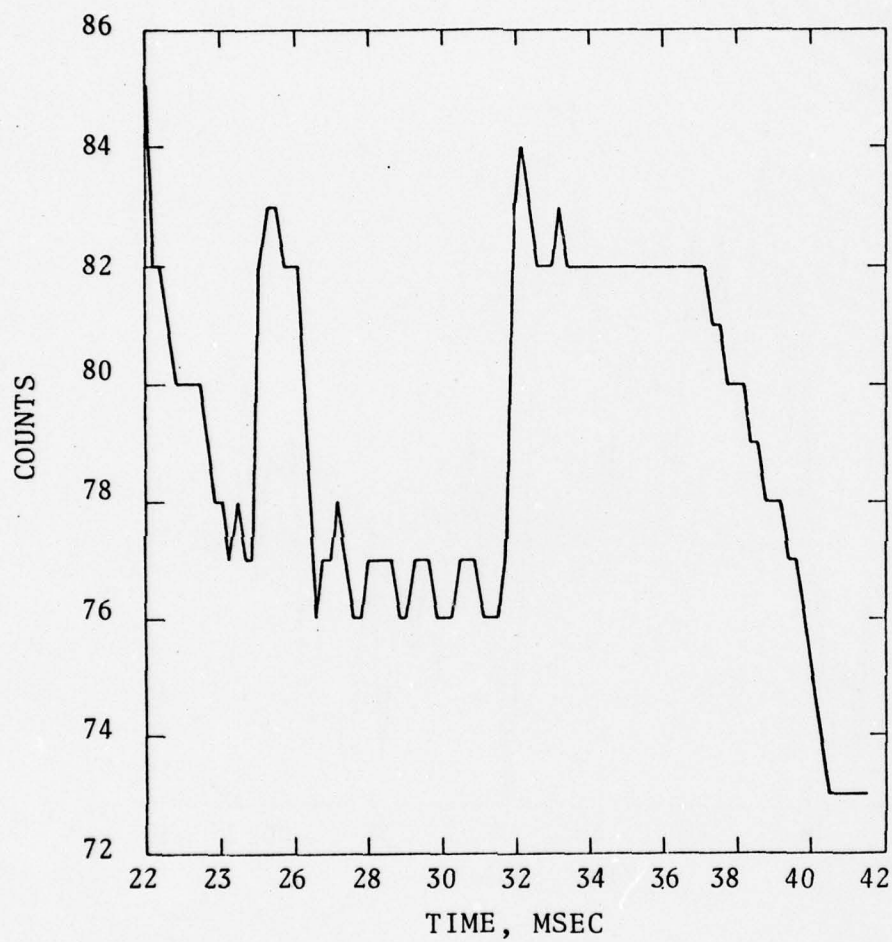


FIGURE 23. CAN B, CHANNEL 4B, JUNE 1976

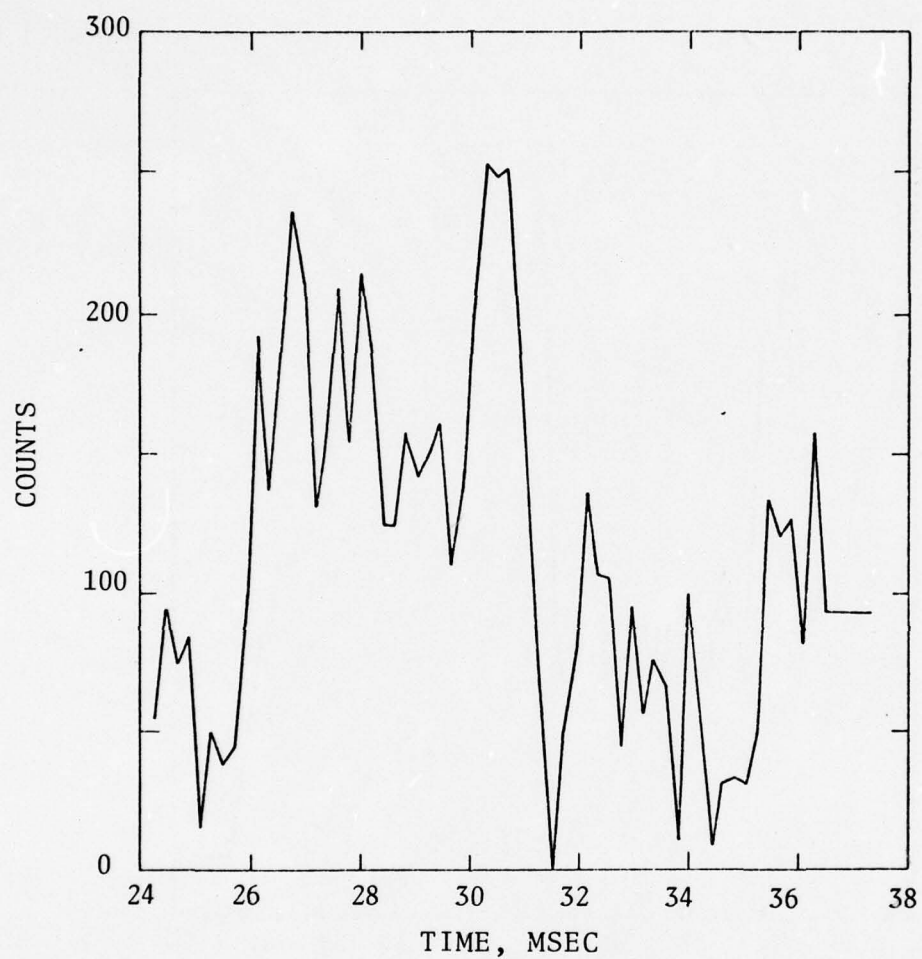


FIGURE 24. CAN B, CHANNEL 4B, JUNE 1976

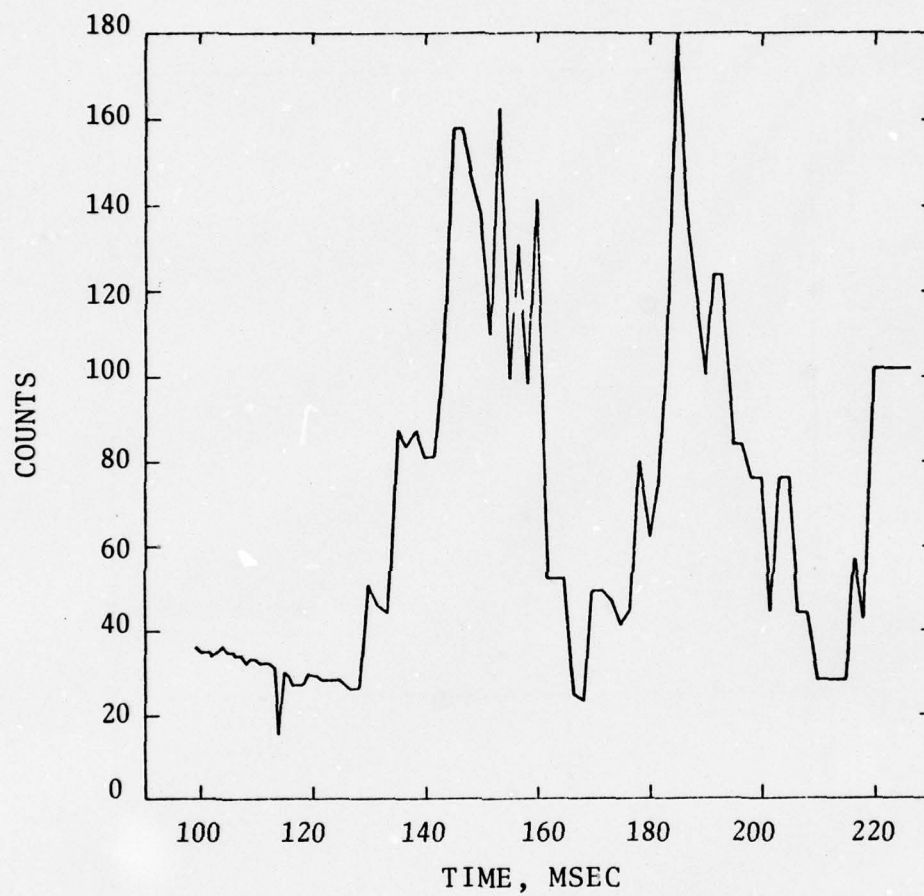


FIGURE 25. CAN B, CHANNEL 4B, JUNE 1976

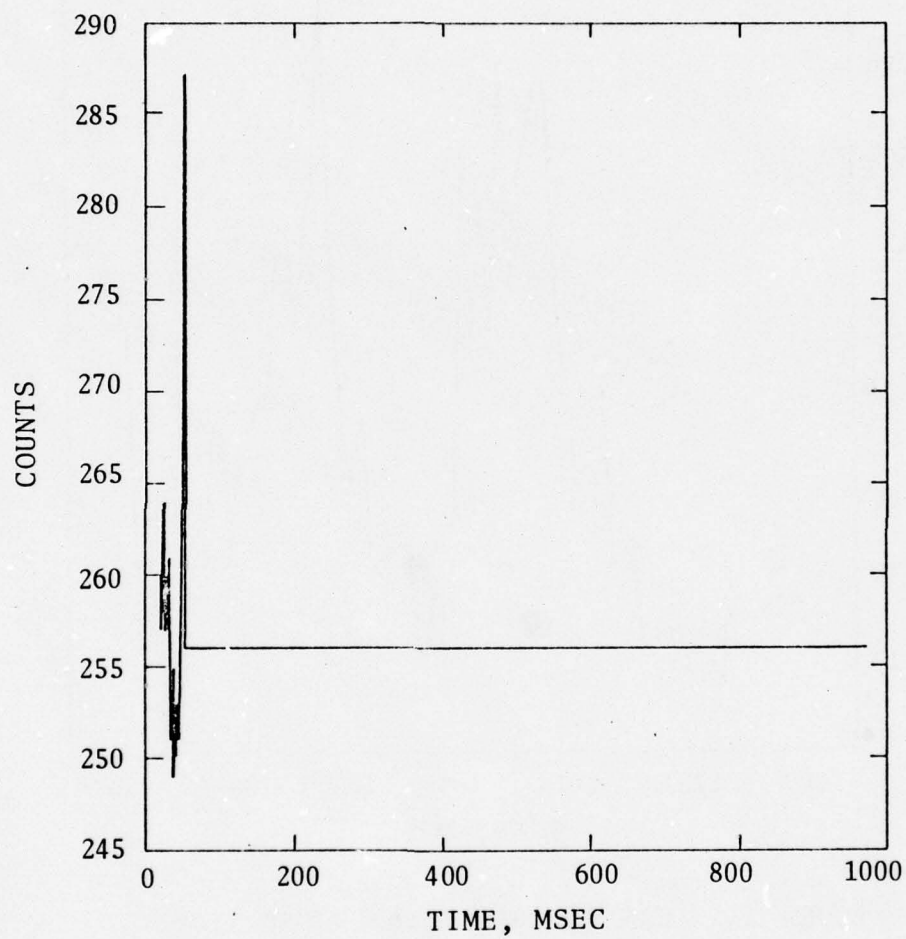


FIGURE 26. CAN B, CHANNEL 5A, MAY 15, 1976

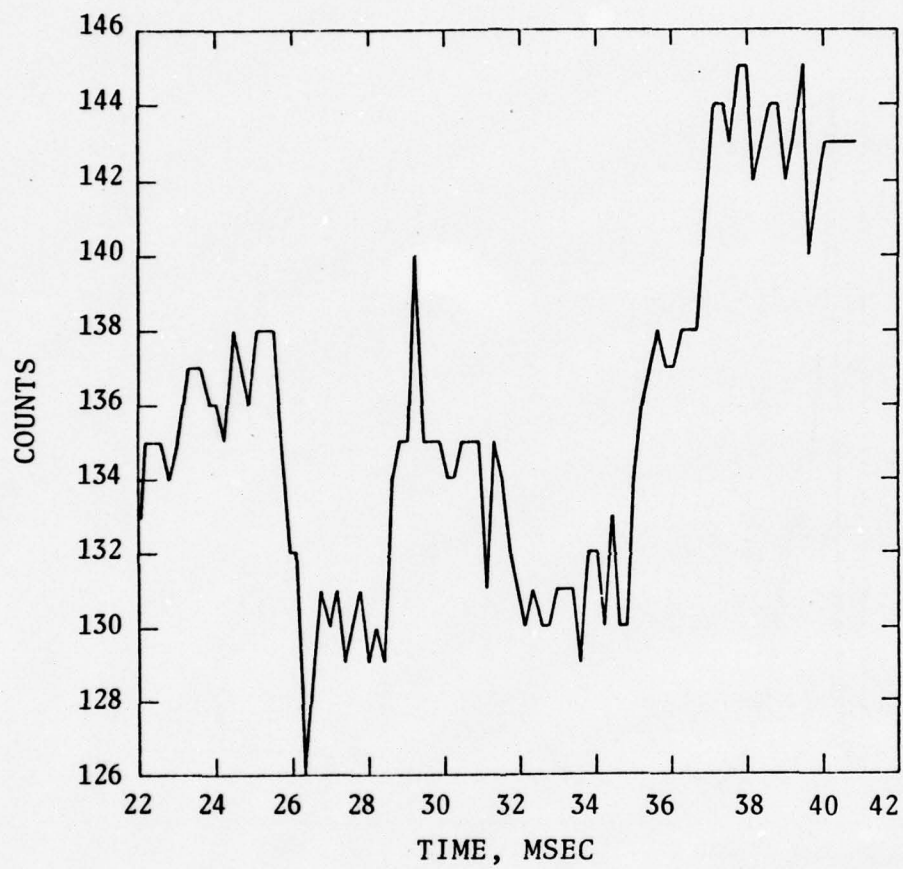


FIGURE 27. CAN B, CHANNEL 5A, JUNE 1976

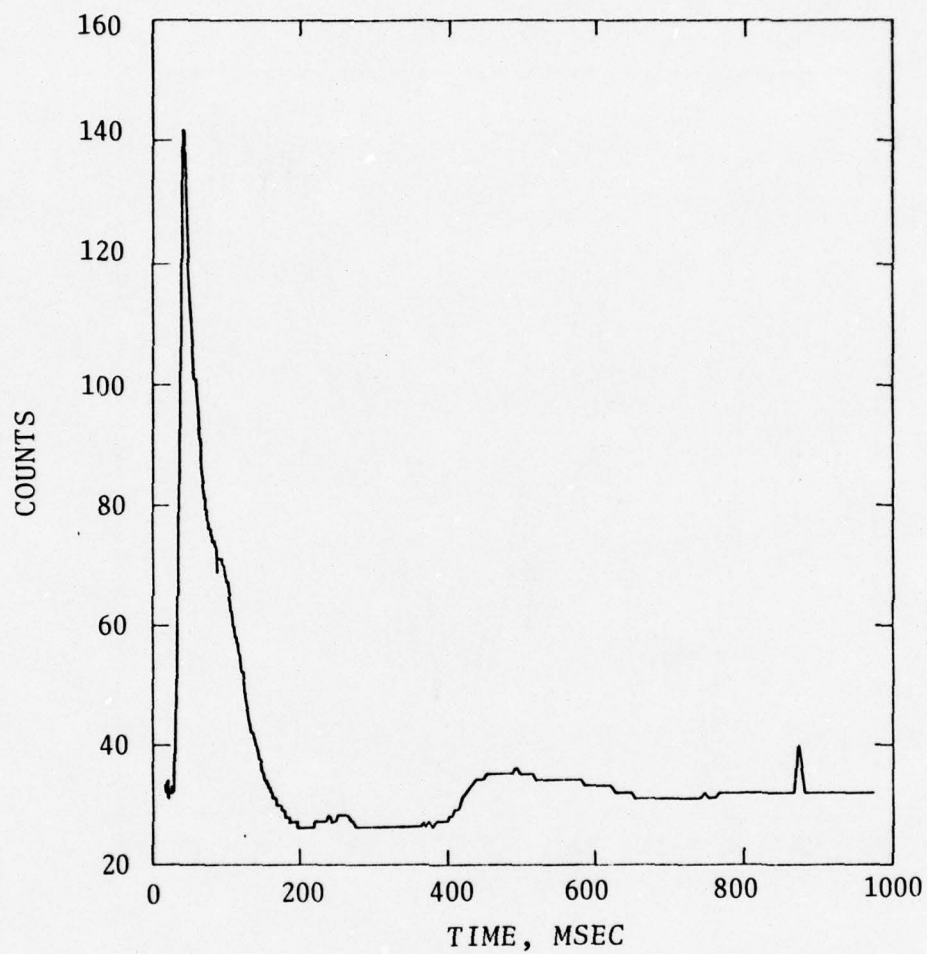


FIGURE 28. CAN B, CHANNEL 5B, MAY 15, 1976

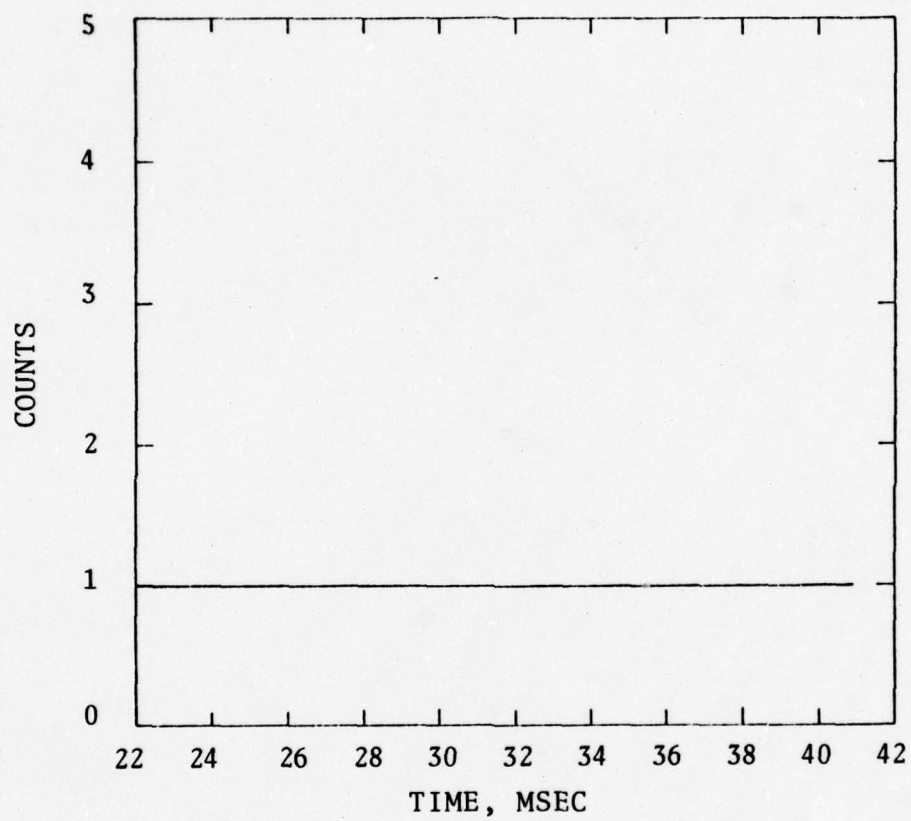


FIGURE 29. CAN B, CHANNEL 5B, JUNE 1976

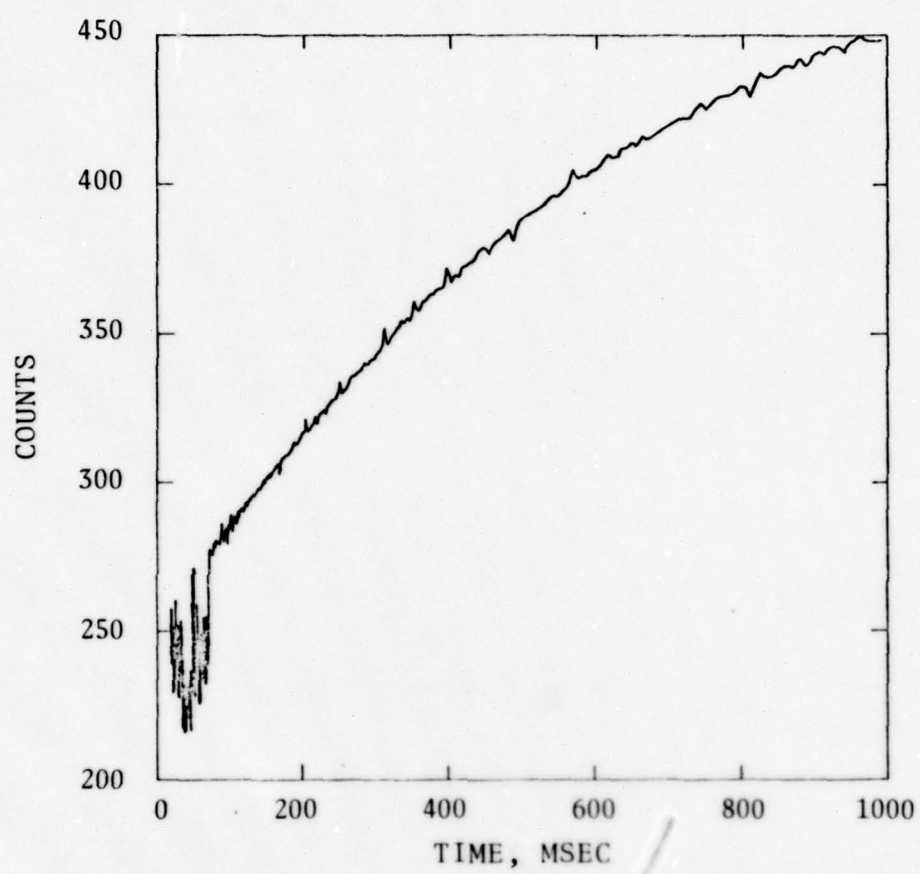


FIGURE 30. CAN B, CHANNEL 6A, MAY 15, 1976

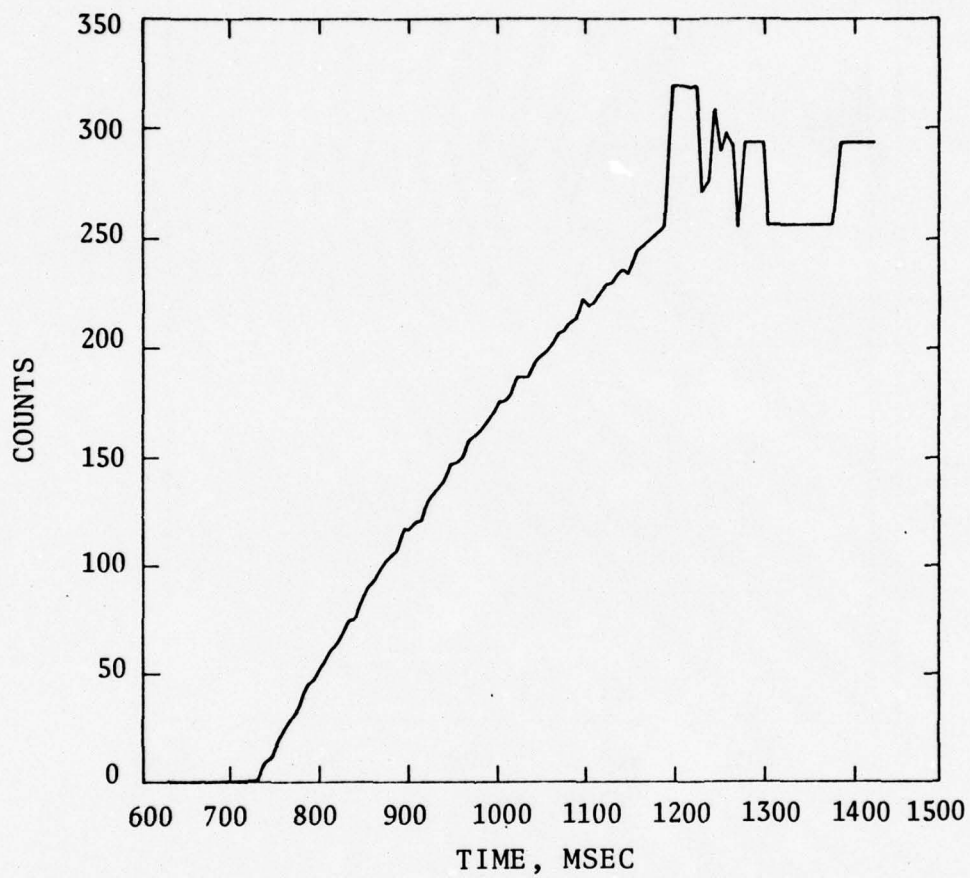


FIGURE 31. CAN B, CHANNEL 6A, MAY 15, 1976

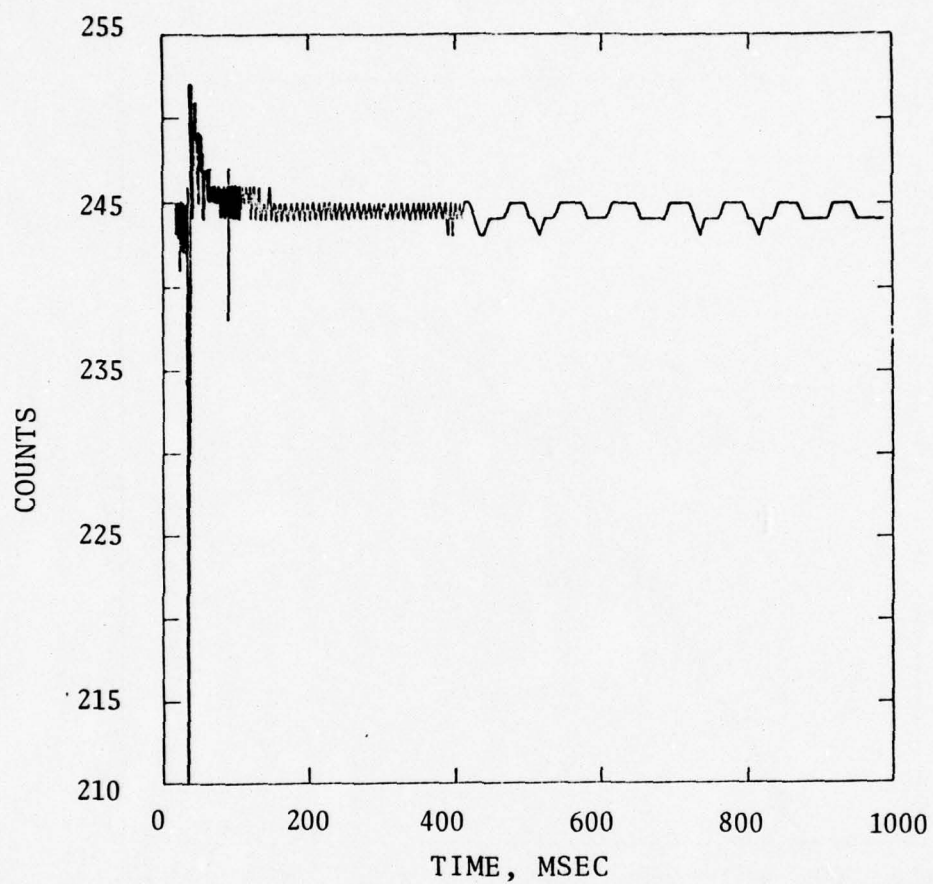


FIGURE 32. CAN B, CHANNEL 6B, MAY 15, 1976

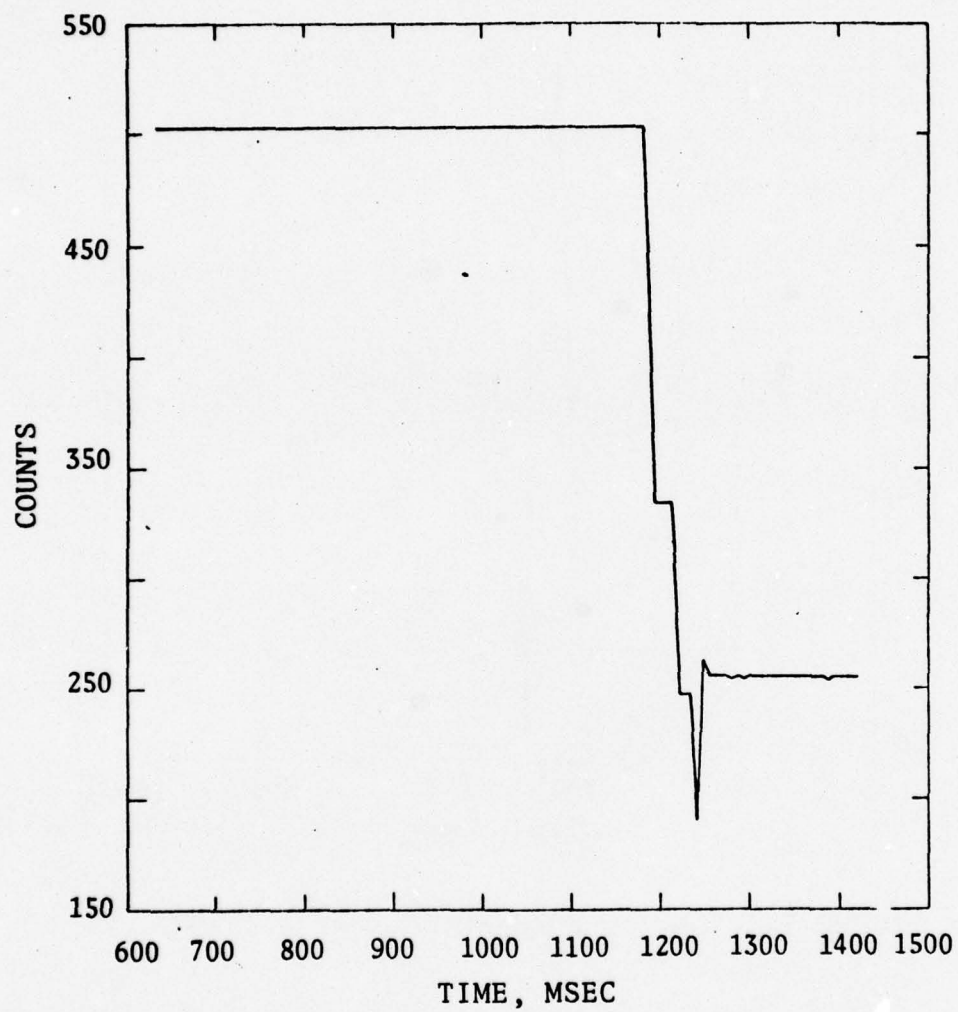


FIGURE 33. CAN B, CHANNEL 6B, MAY 15, 1976

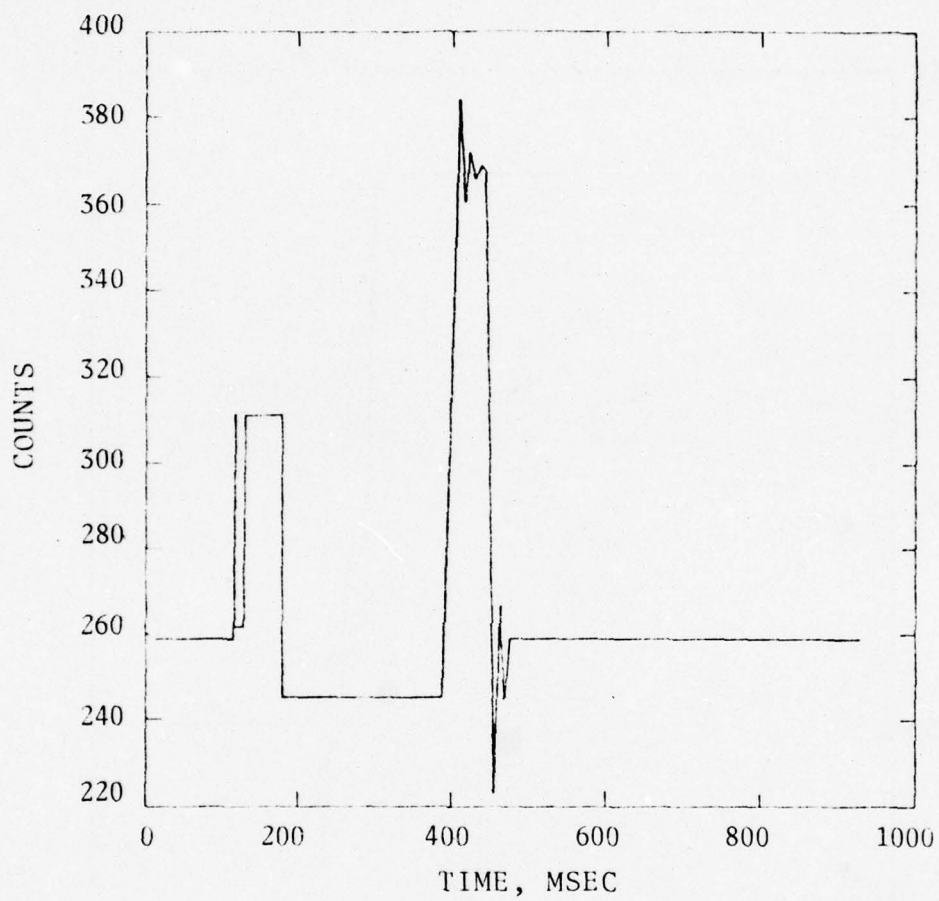


FIGURE 34. CAN A, CHANNEL 1A, MAY 15, 1976

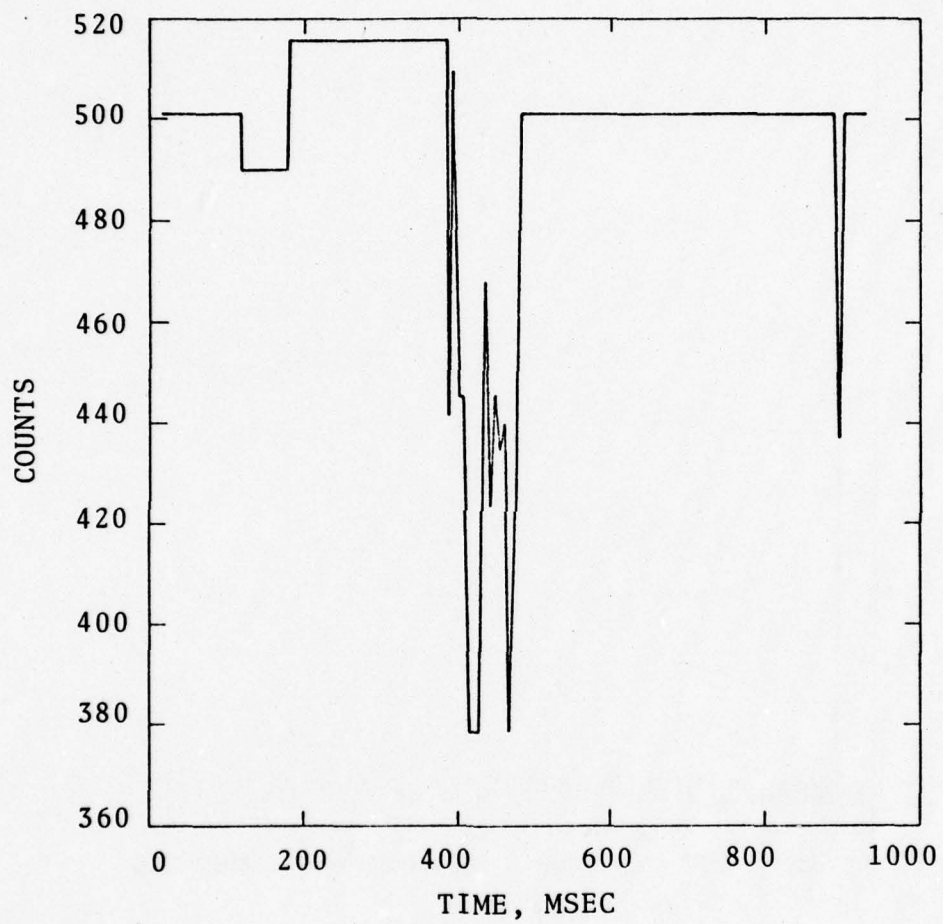


FIGURE 35. CAN A, CHANNEL 1B, MAY 15, 1976

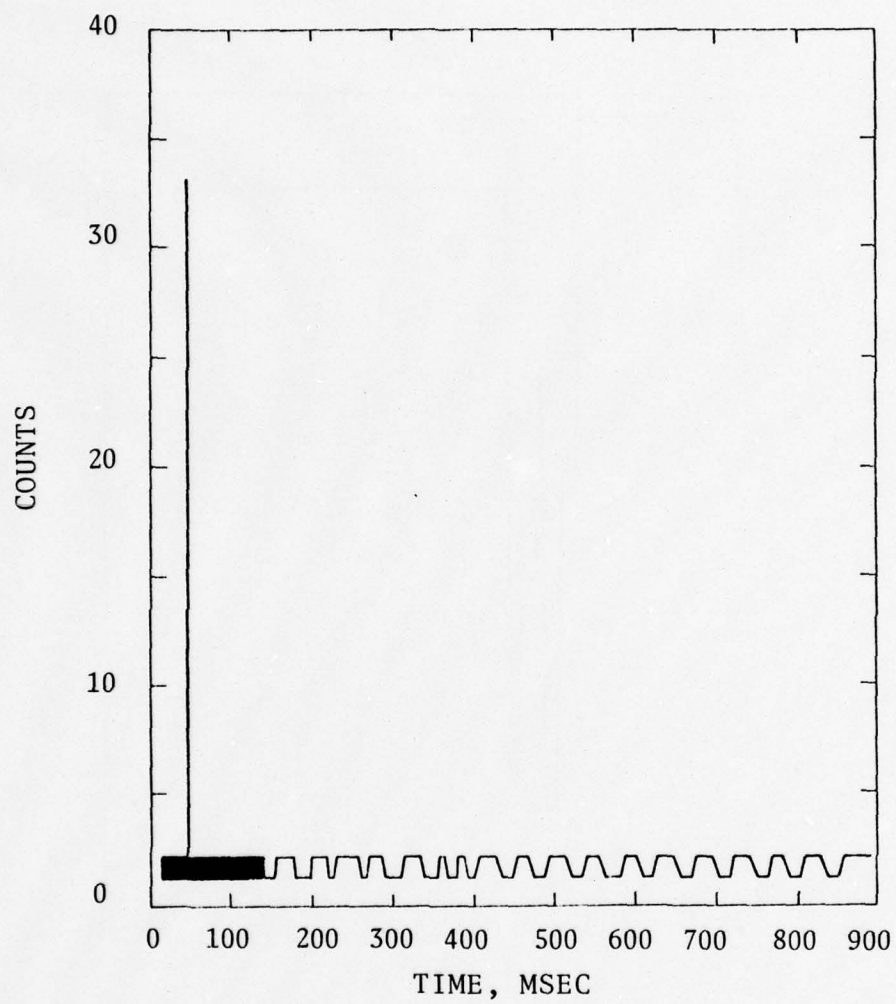


FIGURE 36. CAN A, CHANNEL 2A, MAY 15, 1976

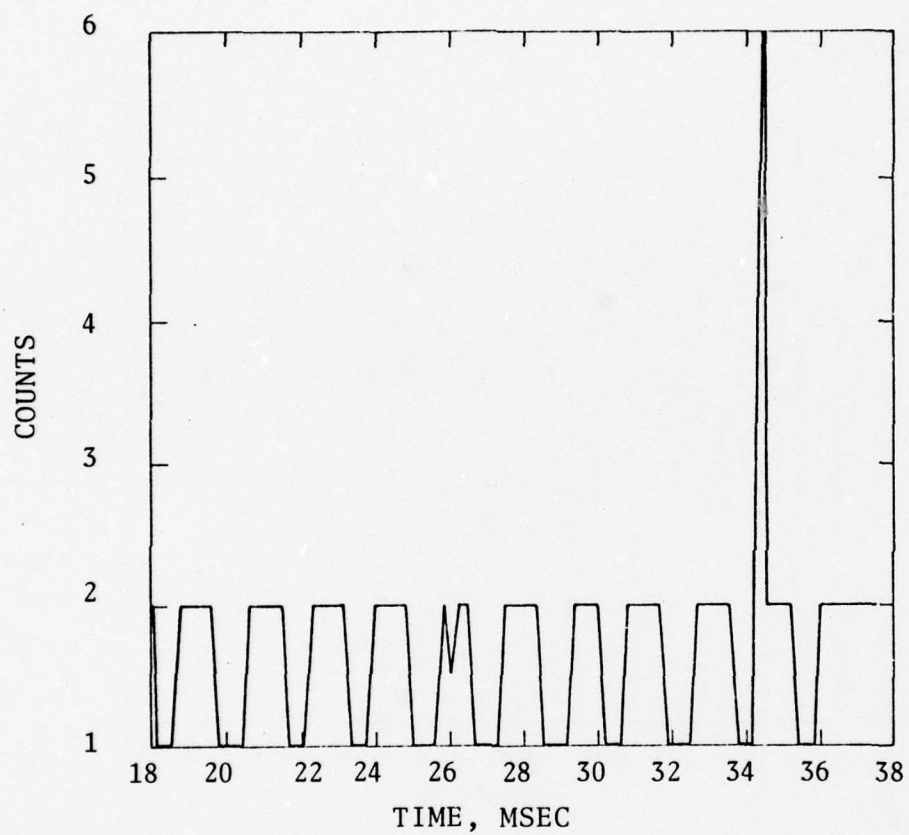


FIGURE 37. CAN A, CHANNEL 2A, JUNE 1976

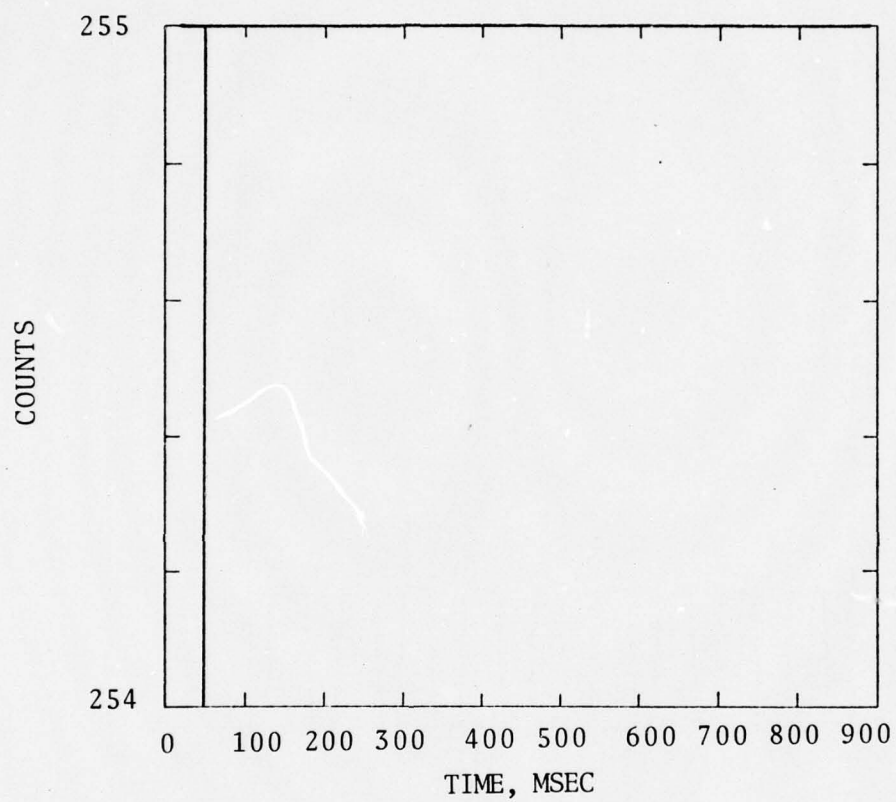


FIGURE 38. CAN A, CHANNEL 2B, MAY 15, 1976

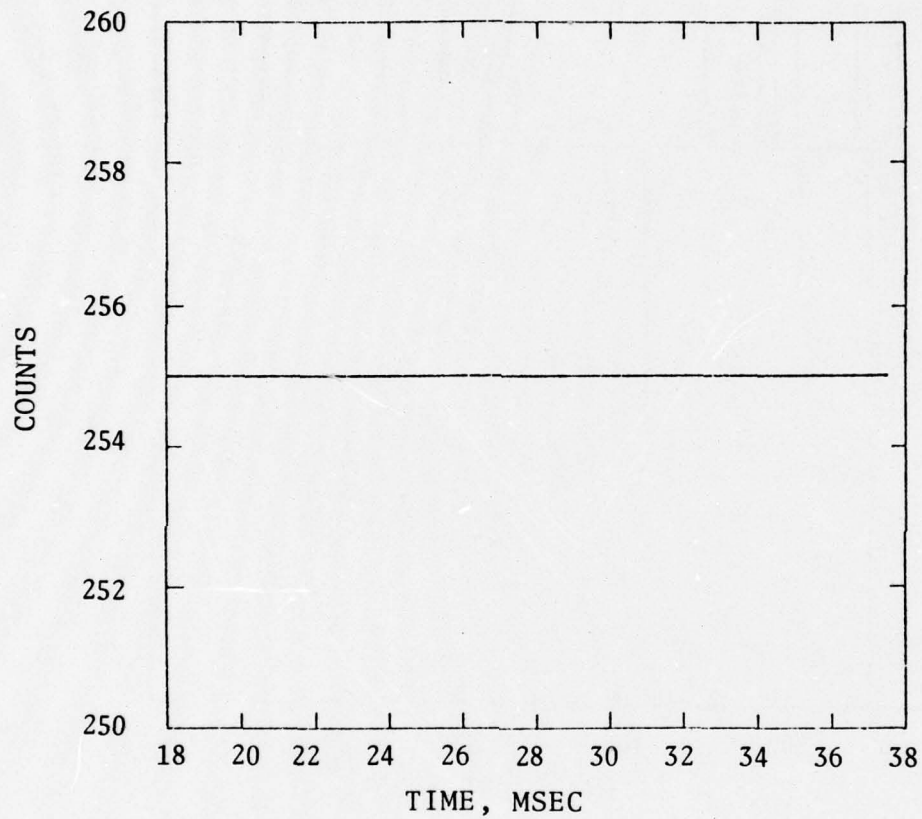


FIGURE 39. CAN A, CHANNEL 2B, JUNE 1976

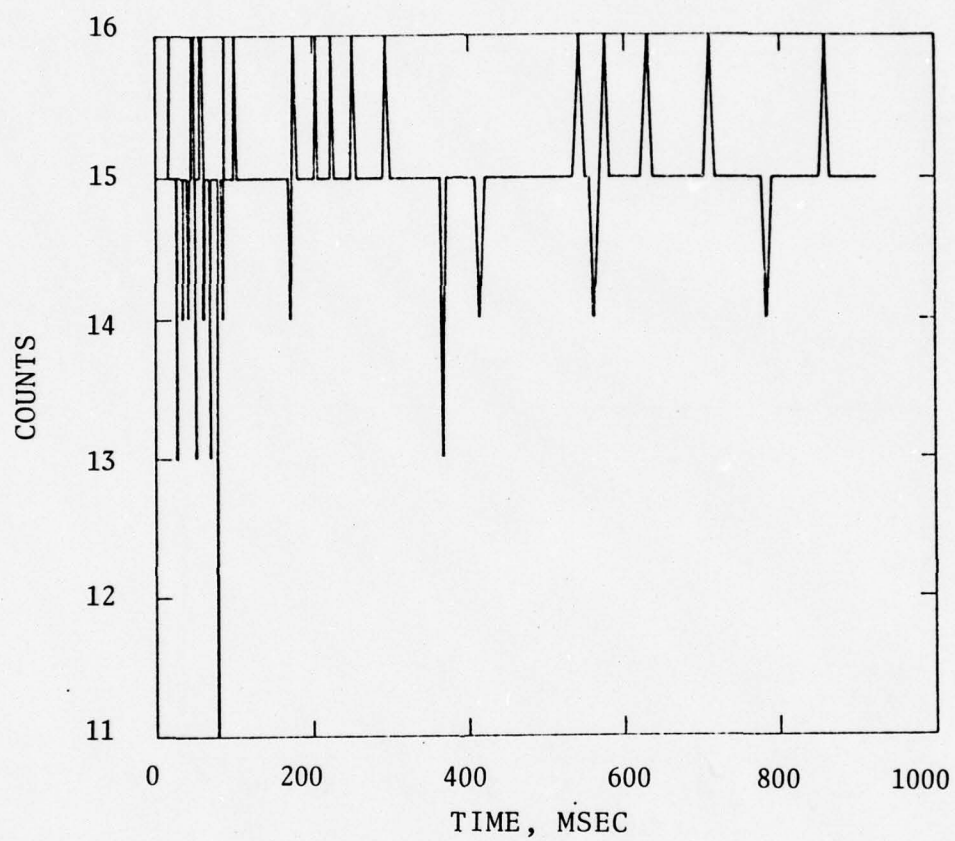


FIGURE 40. CAN A, CHANNEL 3A, MAY 15, 1976

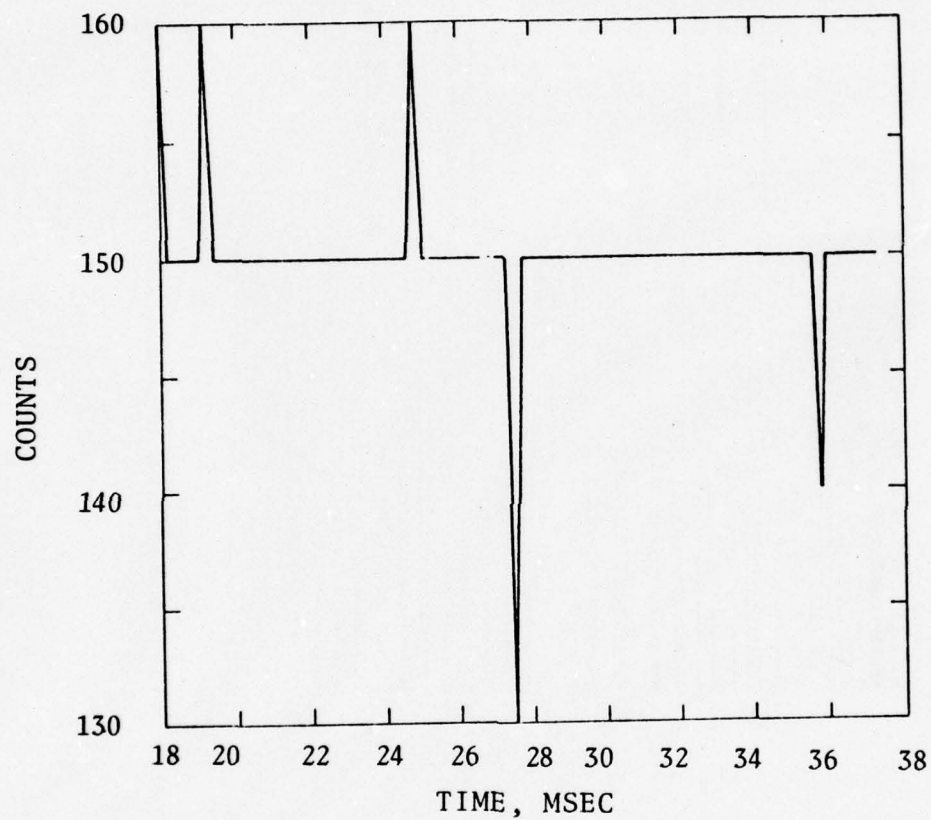


FIGURE 41. CAN A, CHANNEL 3A, JUNE 1976

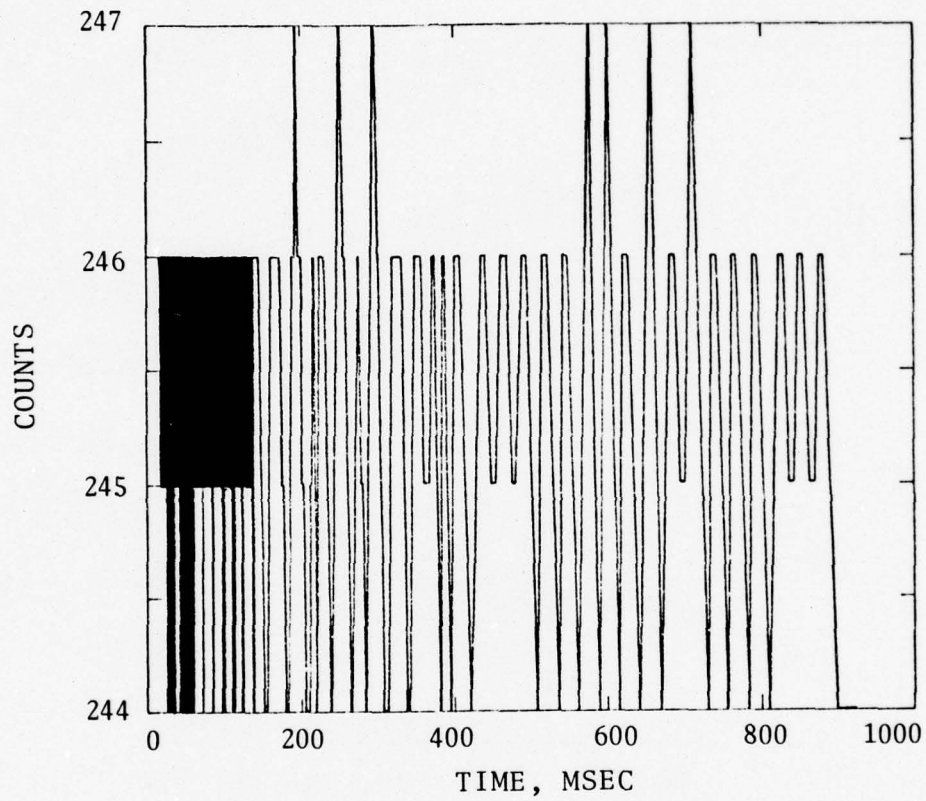


FIGURE 42. CAN A, CHANNEL 3B, MAY 15, 1976

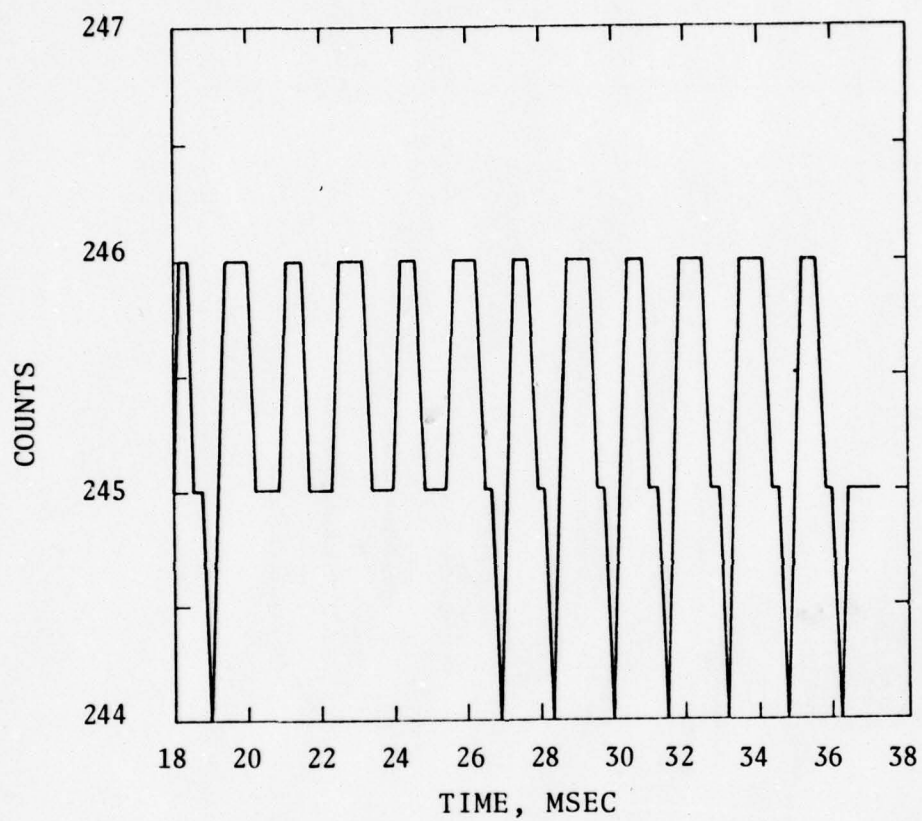


FIGURE 43. CAN A, CHANNEL 3B, JUNE 1976

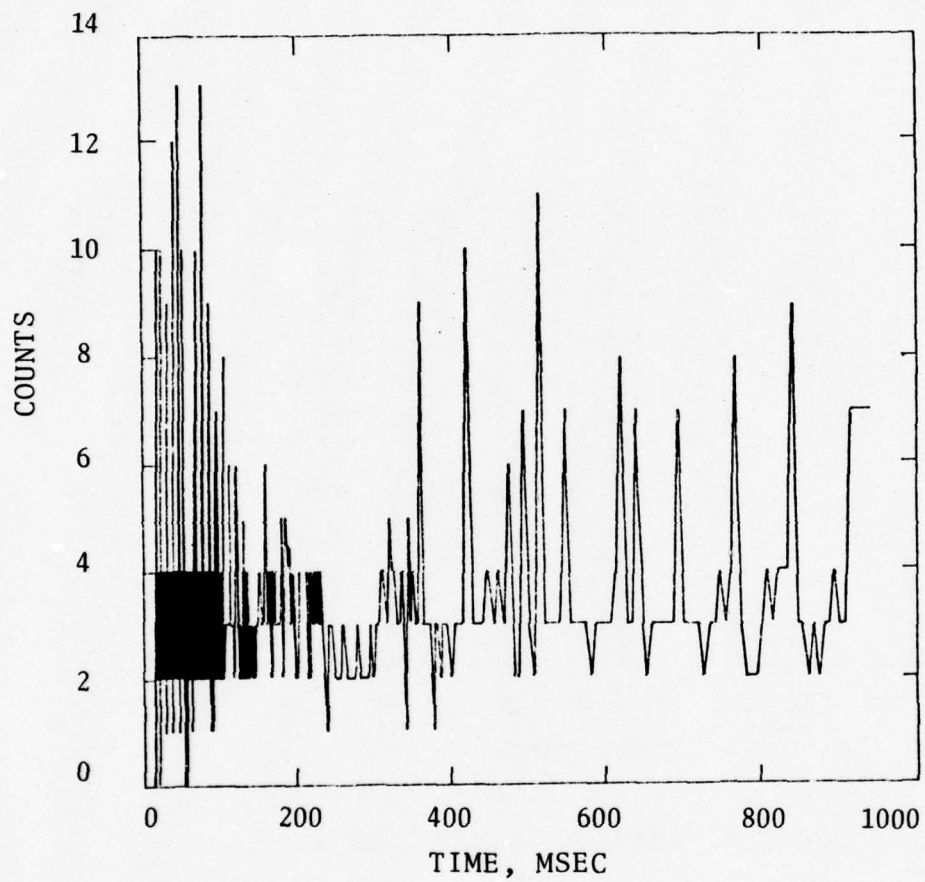


FIGURE 44. CAN A, CHANNEL 4A, MAY 15, 1976

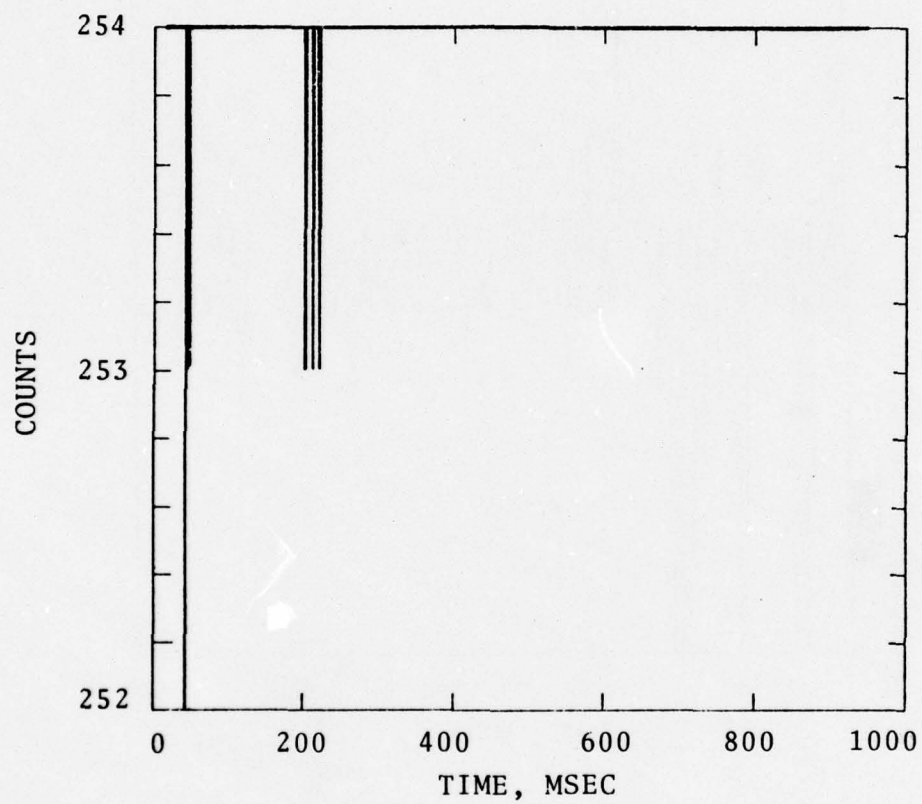


FIGURE 45. CAN A, CHANNEL 4B, MAY 15, 1976

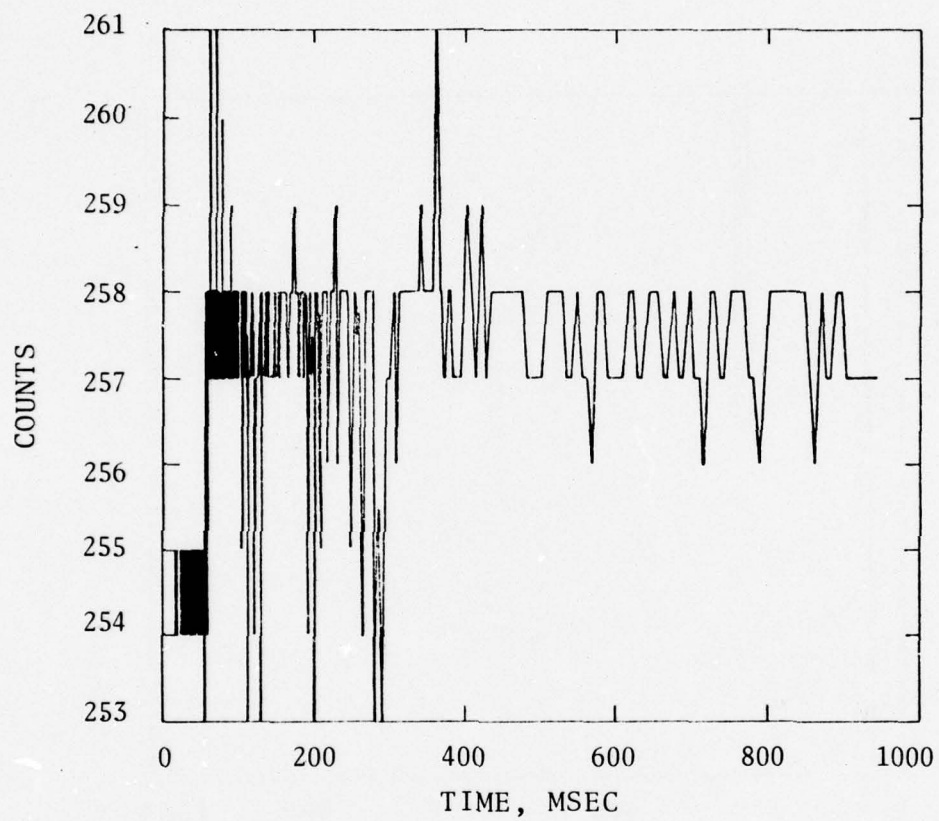


FIGURE 46. CAN A, CHANNEL 5A, MAY 15, 1976

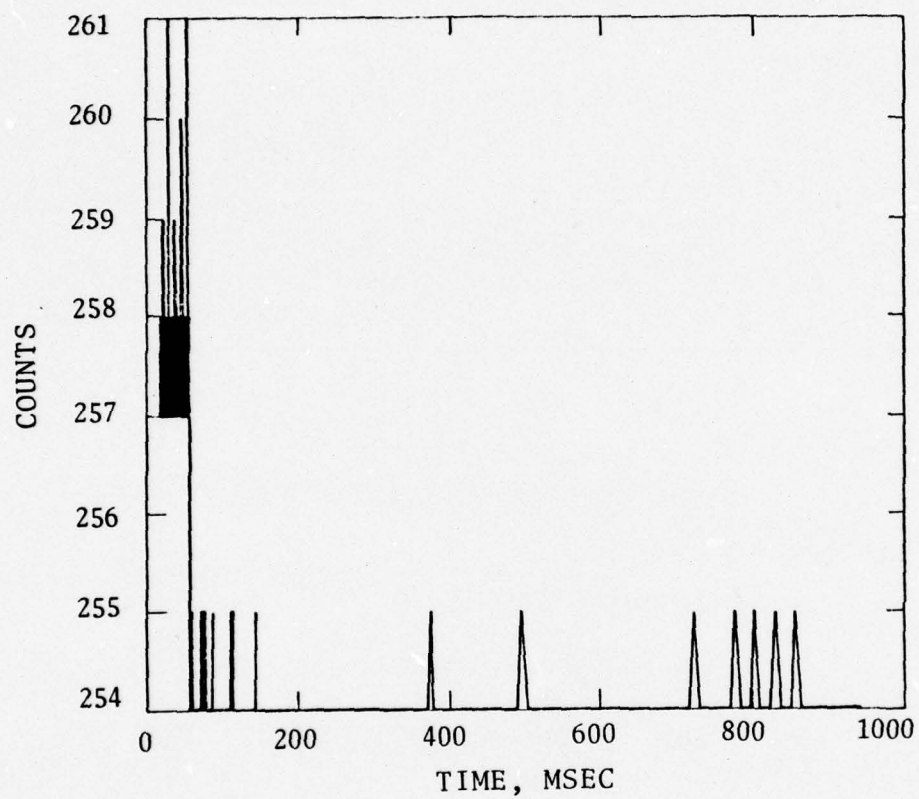


FIGURE 47. CAN A, CHANNEL 5B, MAY 15, 1976

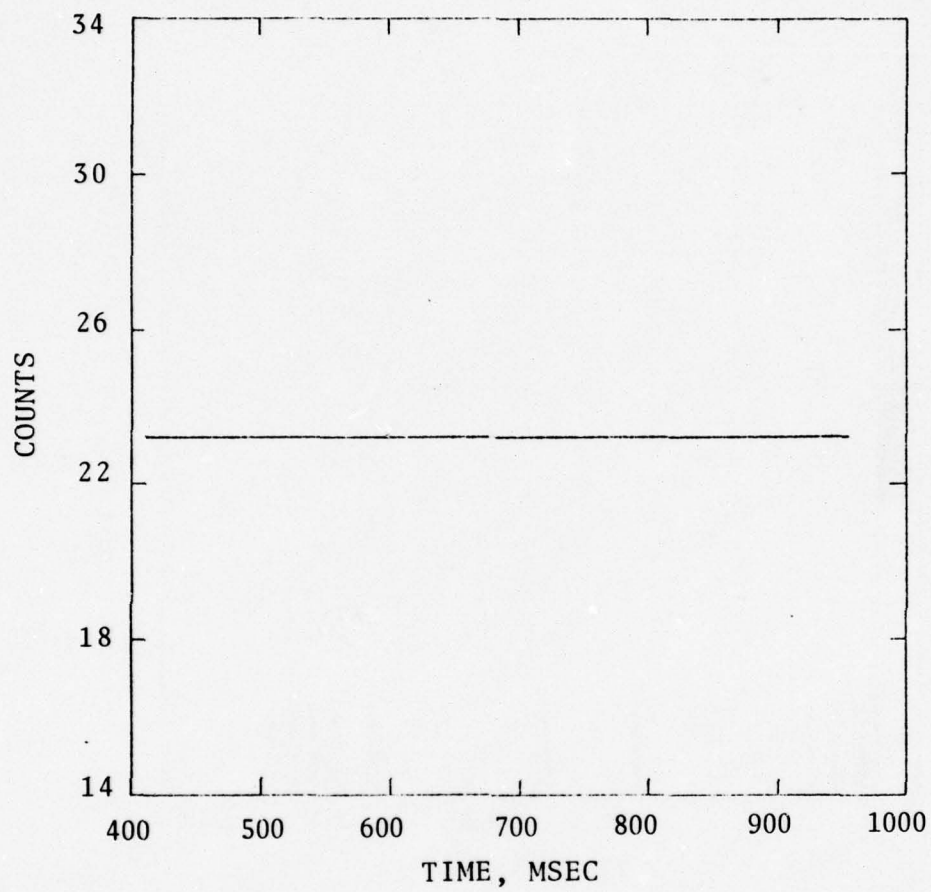


FIGURE 48. CAN C, CHANNEL 1A, MAY 15, 1976

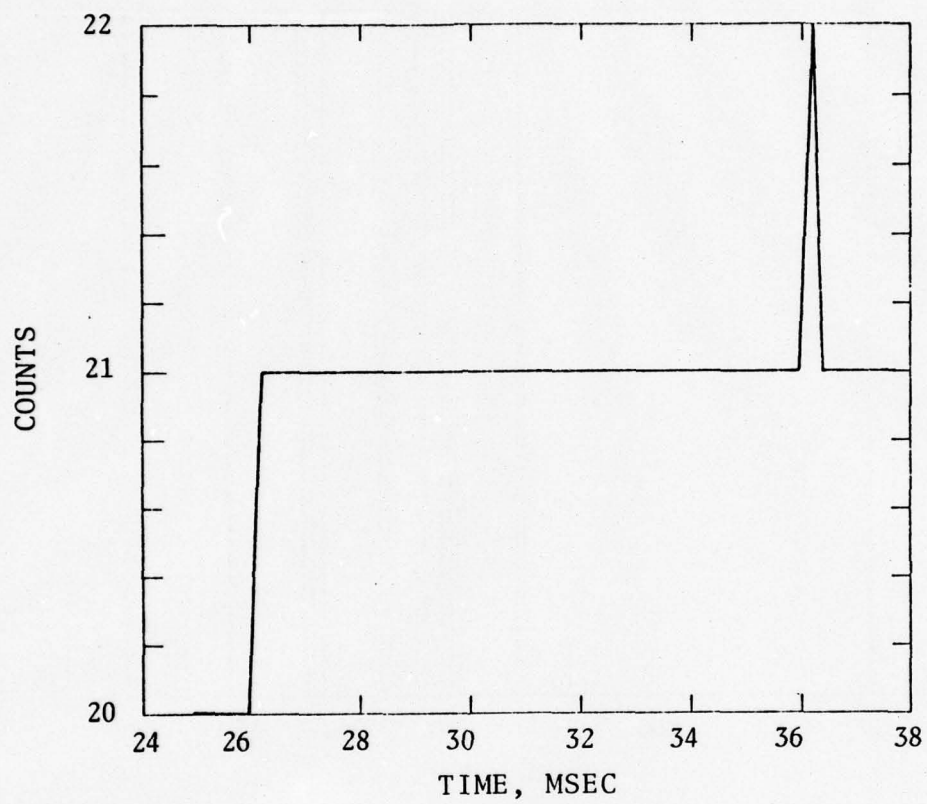


FIGURE 49. CAN C, CHANNEL 1A, MAY 16, 1976

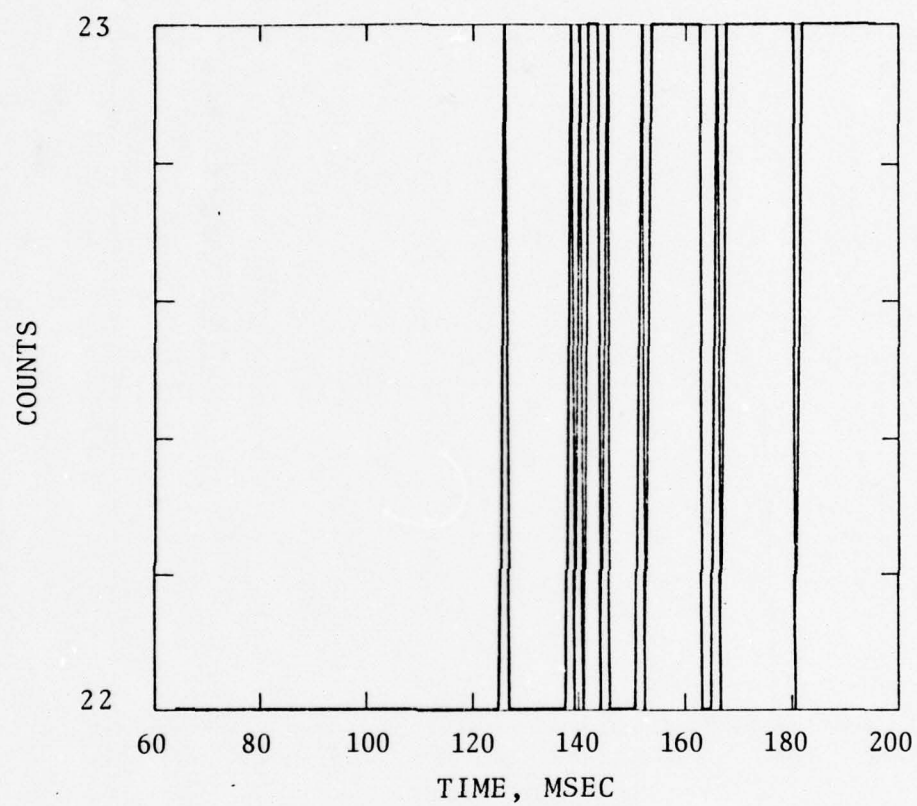


FIGURE 50. CAN C, CHANNEL 1A, MAY 16, 1976

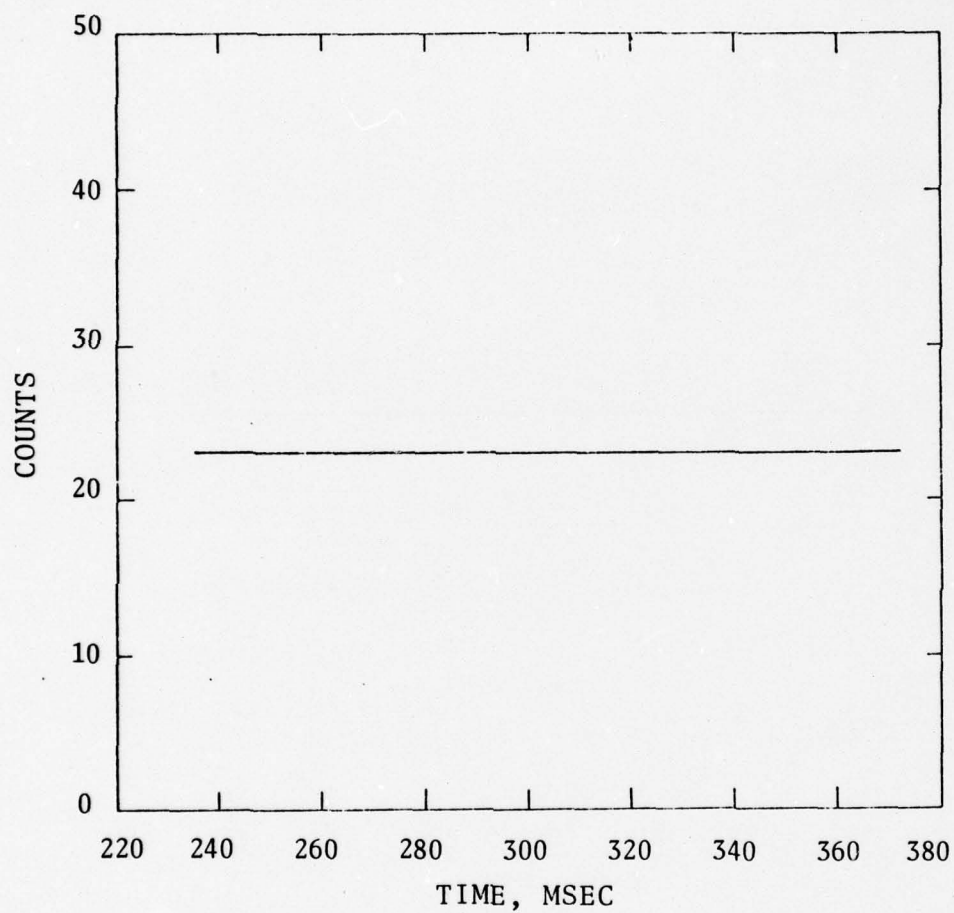


FIGURE 51. CAN C, CHANNEL 1A, MAY 16, 1976

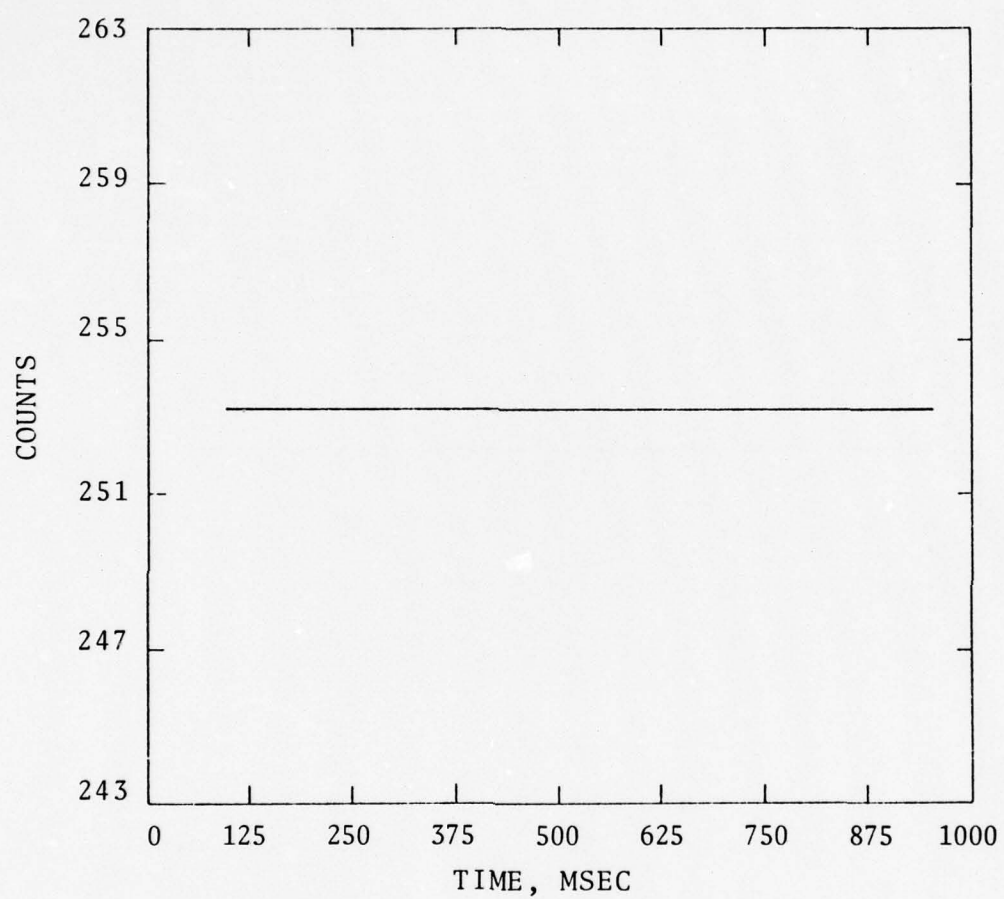


FIGURE 52. CAN C, CHANNEL 1B, MAY 15, 1976

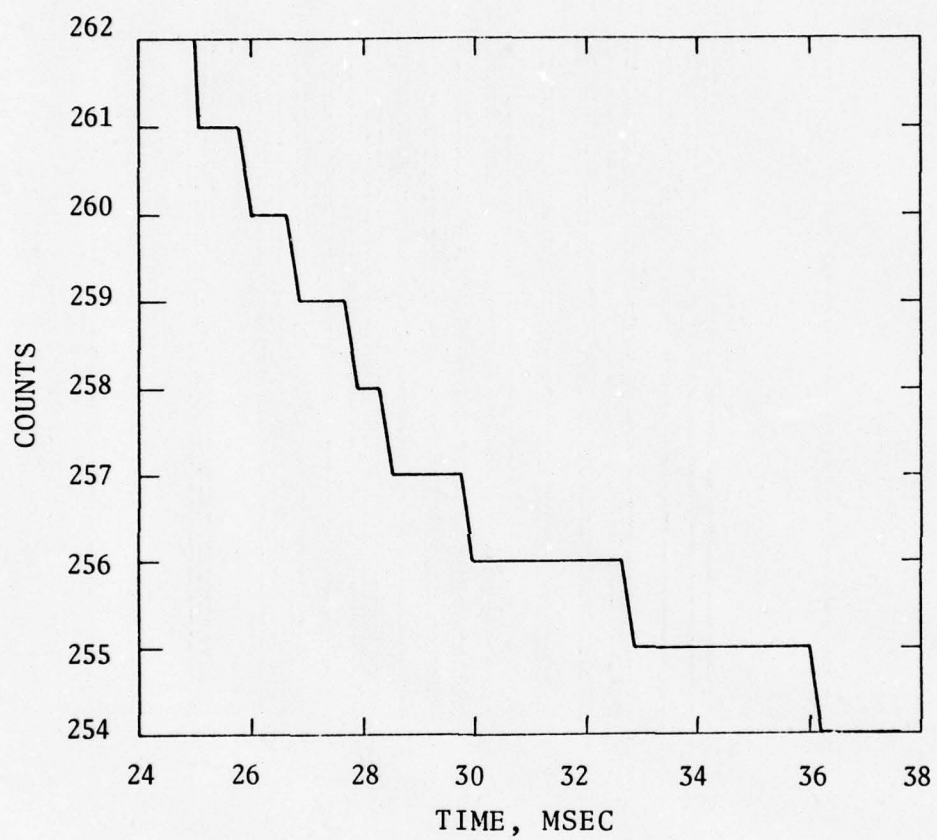


FIGURE 53. CAN C, CHANNEL 1B, MAY 16, 1976

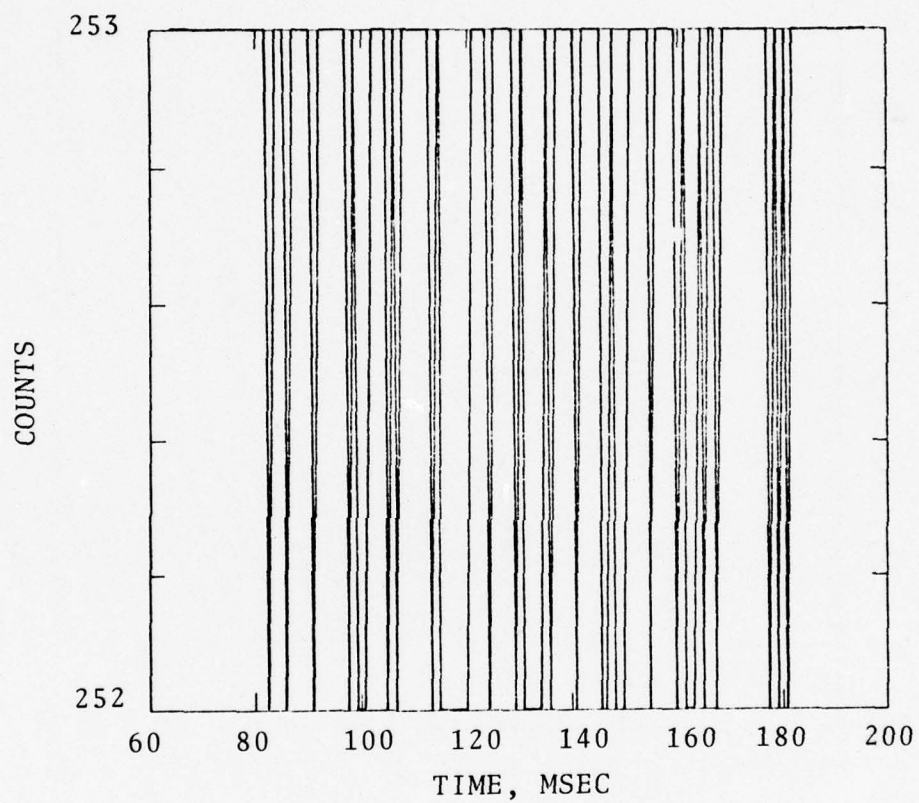


FIGURE 54. CAN C, CHANNEL 1B, MAY 16, 1976

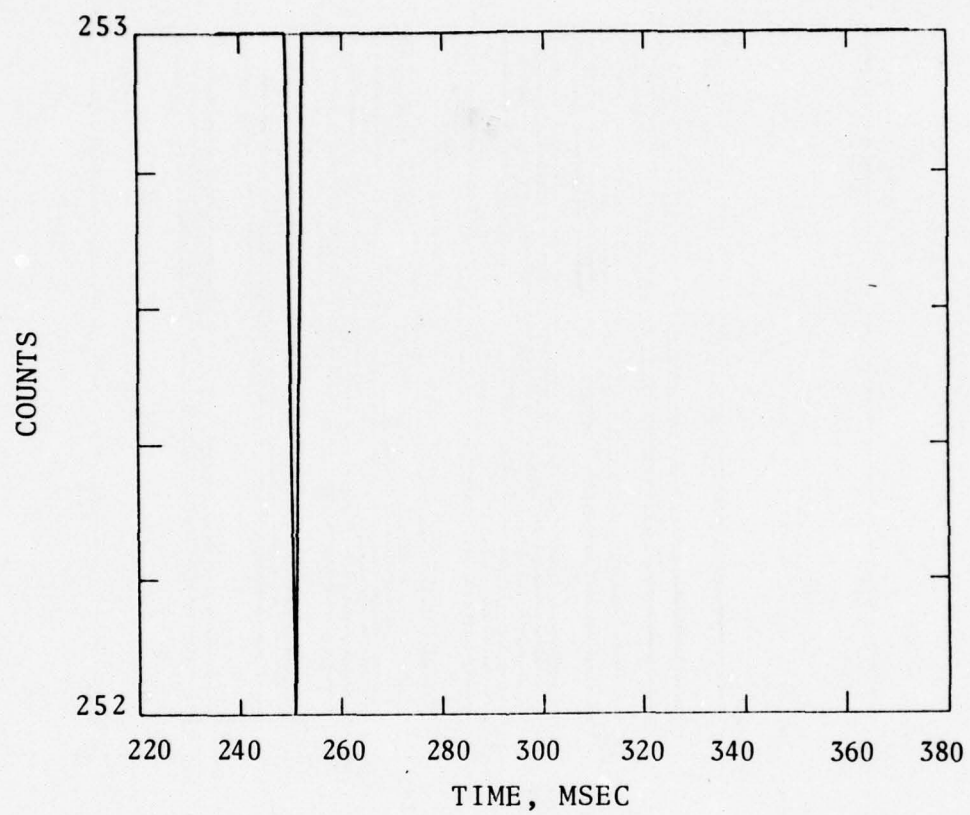


FIGURE 55. CAN C, CHANNEL 1B, MAY 16, 1976

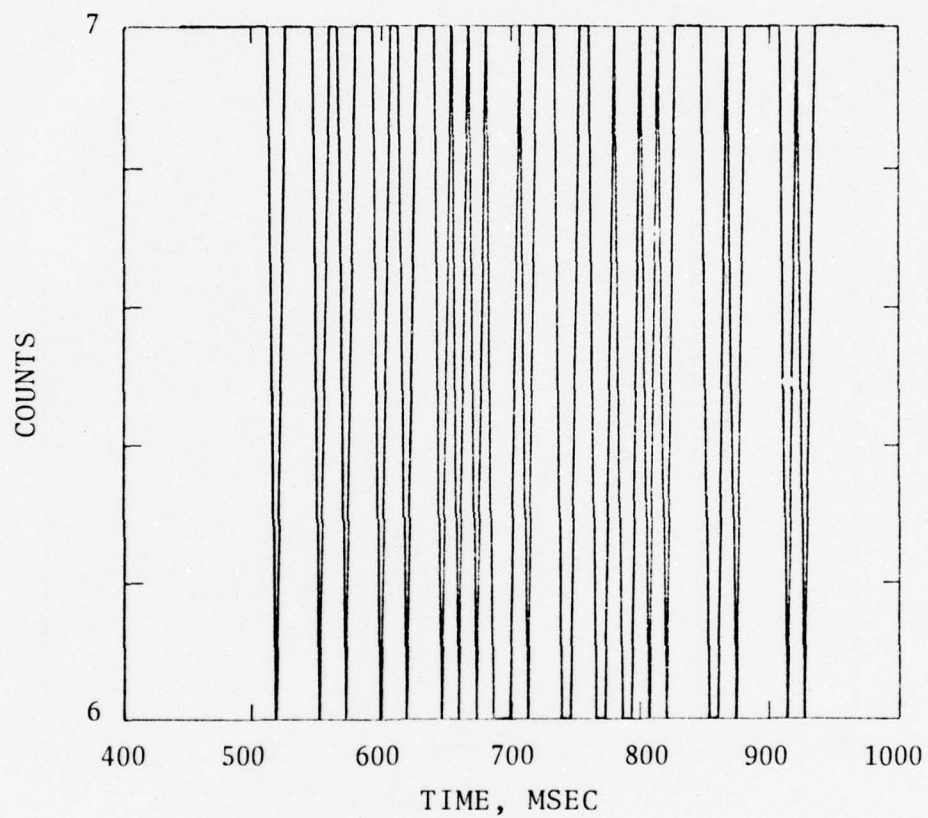
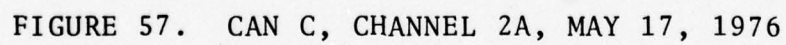


FIGURE 56. CAN C, CHANNEL 2A, MAY 15, 1976



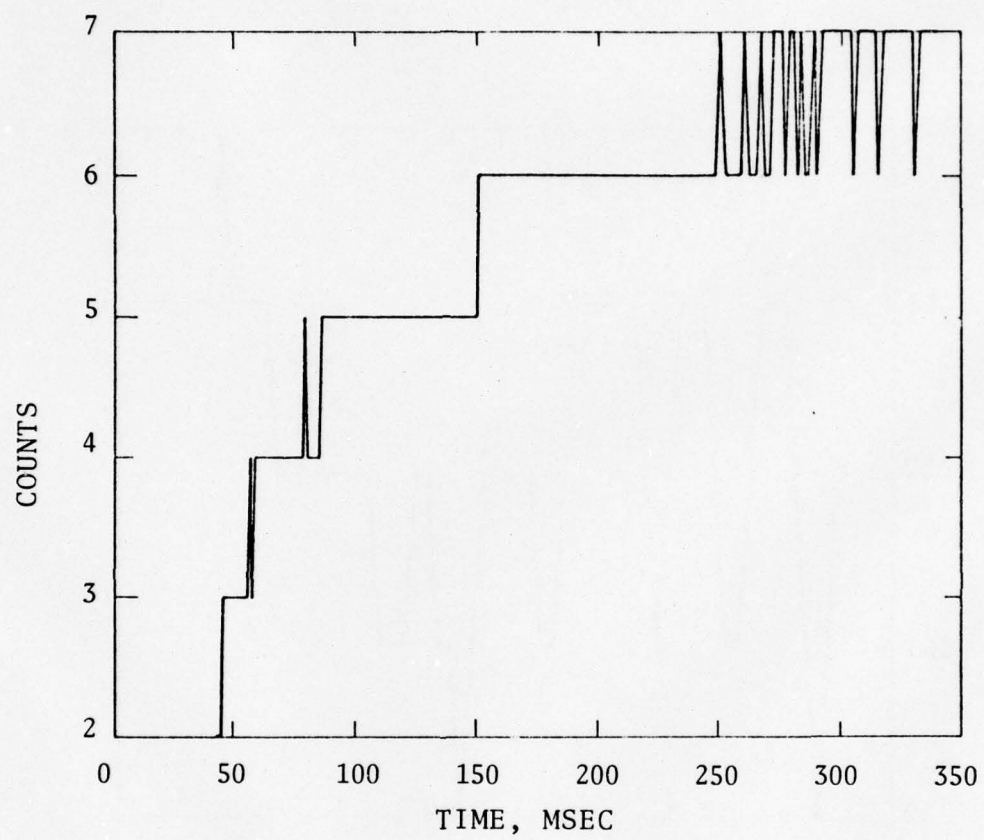


FIGURE 58. CAN C, CHANNEL 2A, MAY 16, 1976

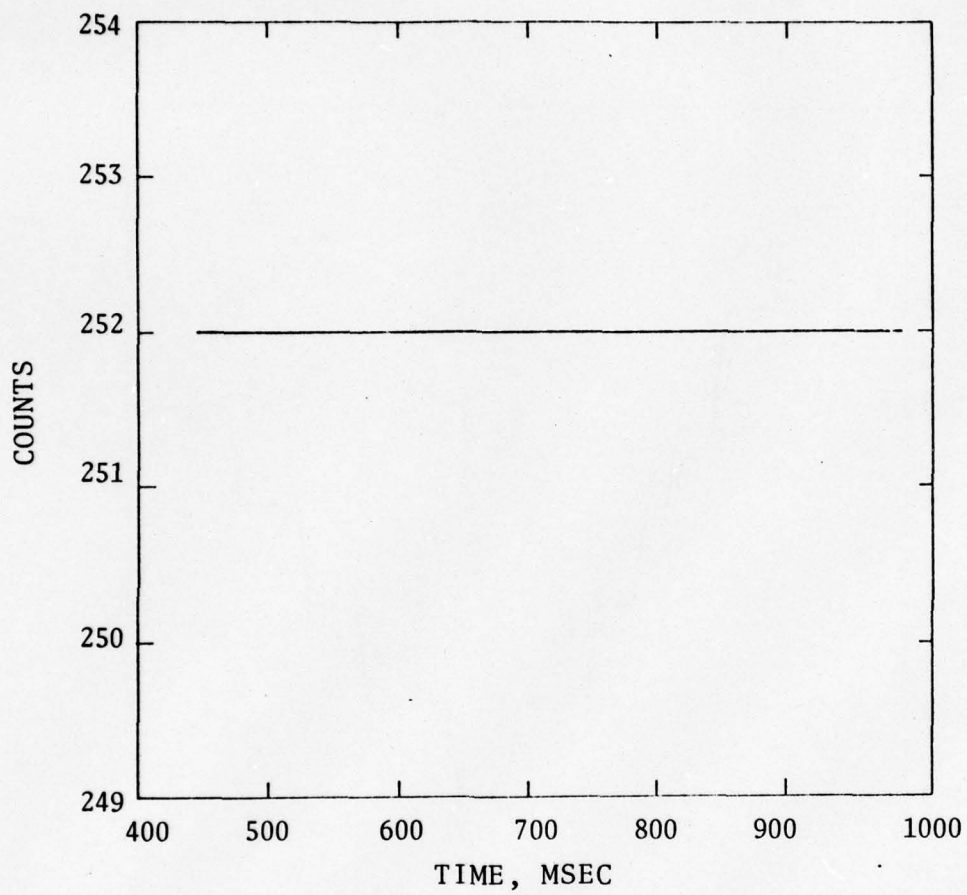


FIGURE 59. CAN C, CHANNEL 2B, MAY 15, 1976

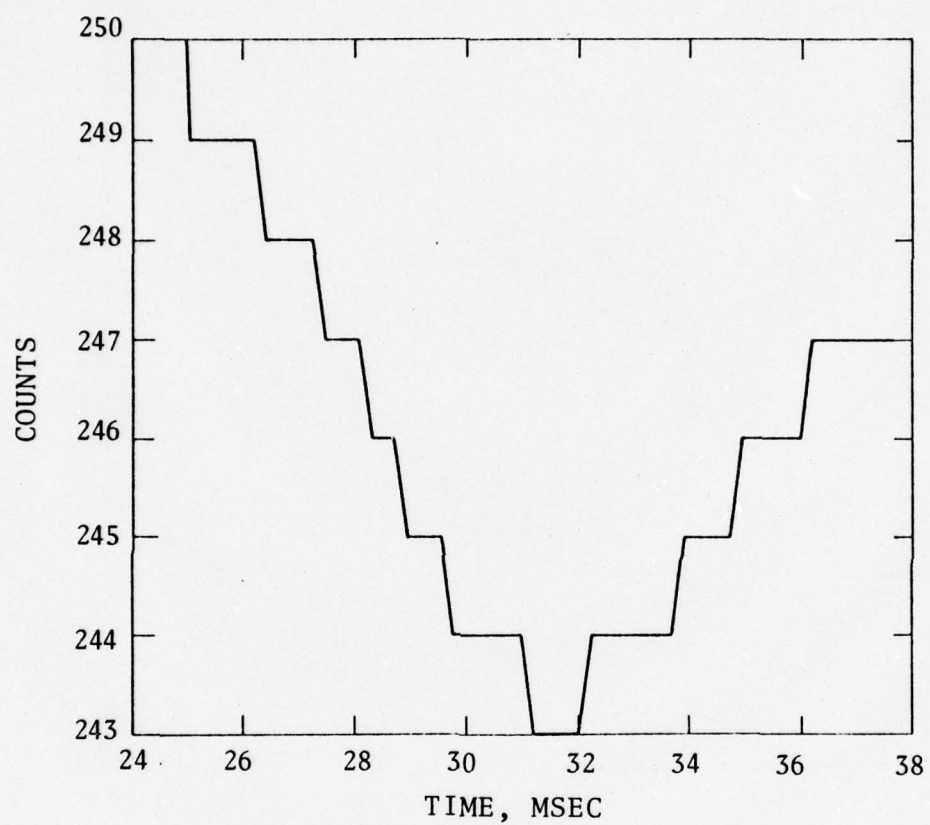


FIGURE 60. CAN C, CHANNEL 2B, MAY 16, 1976

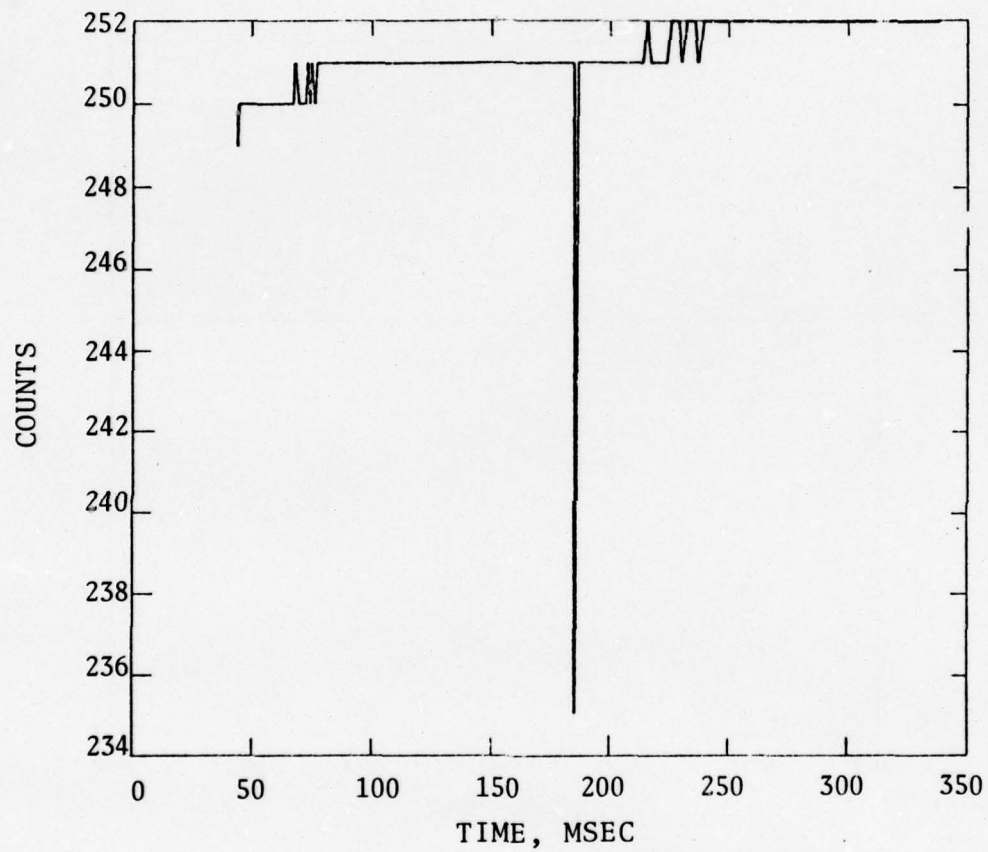


FIGURE 61. CAN C, CHANNEL 2B, MAY 16, 1976

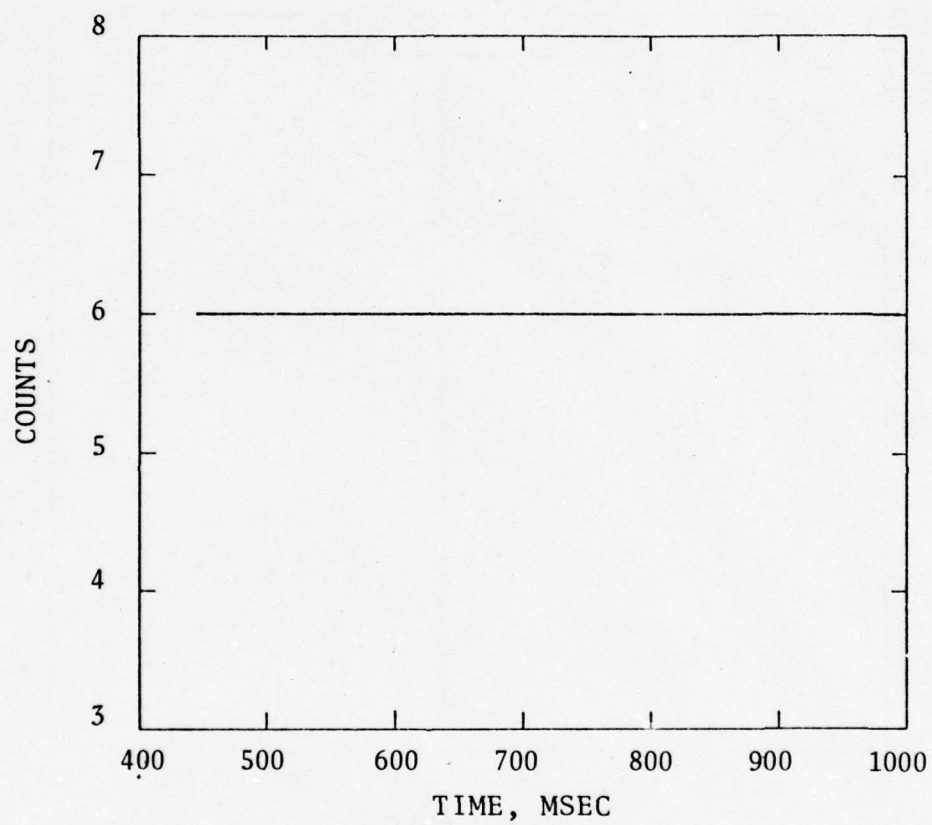


FIGURE 62. CAN C, CHANNEL 3A, MAY 15, 1976

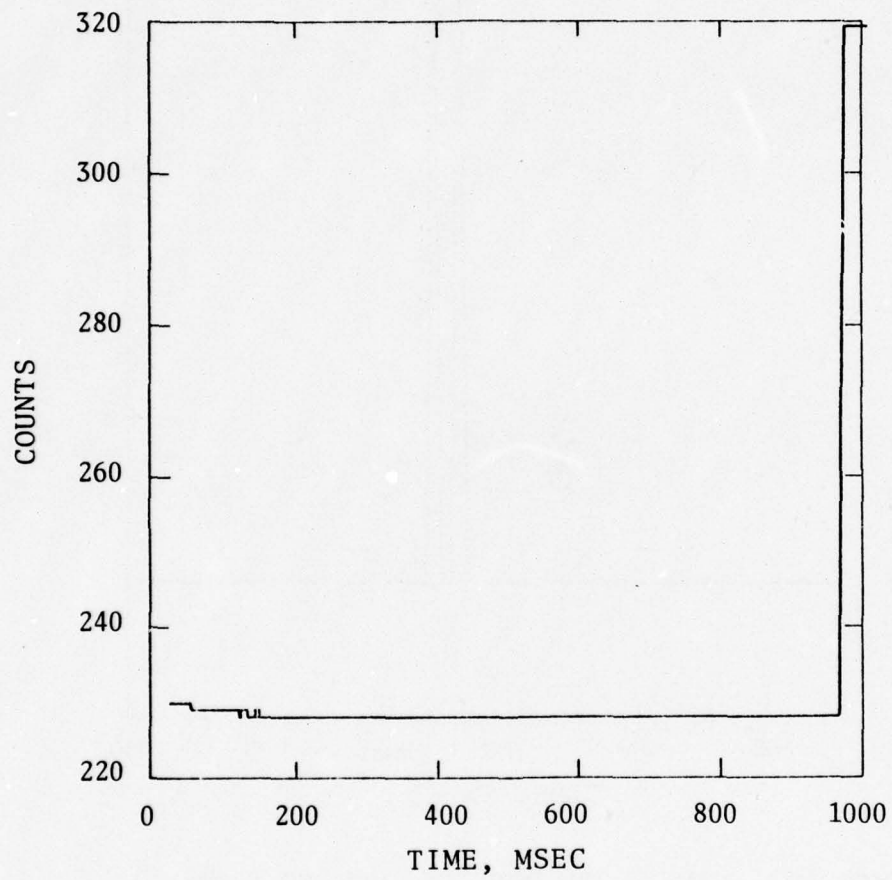


FIGURE 63. CAN C, CHANNEL 3A, MAY 16, 1976

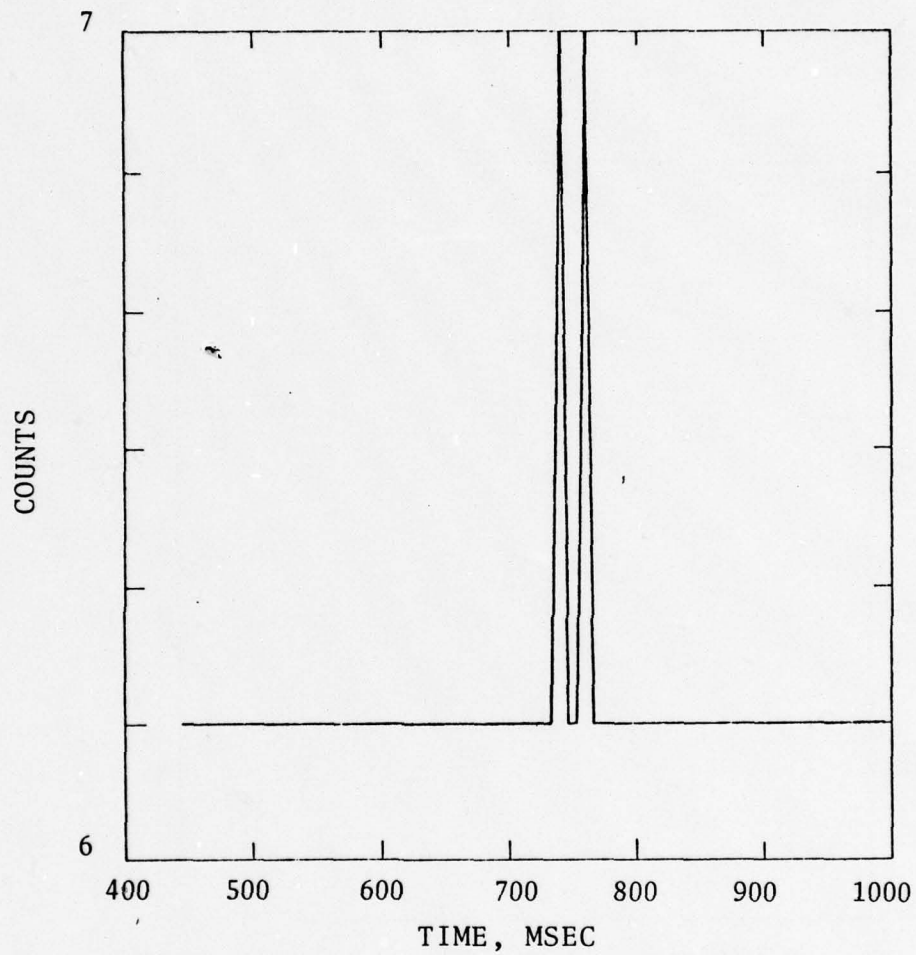


FIGURE 64. CAN C, CHANNEL 3B, MAY 15, 1976

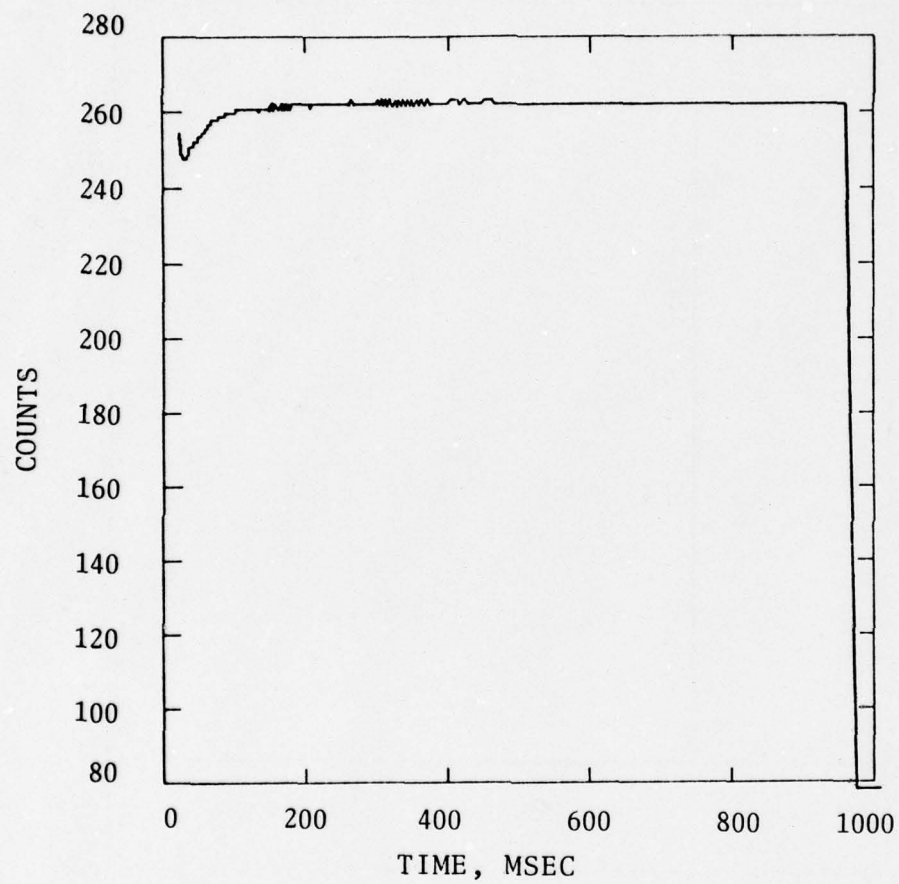


FIGURE 65. CAN C, CHANNEL 3B, MAY 16, 1976

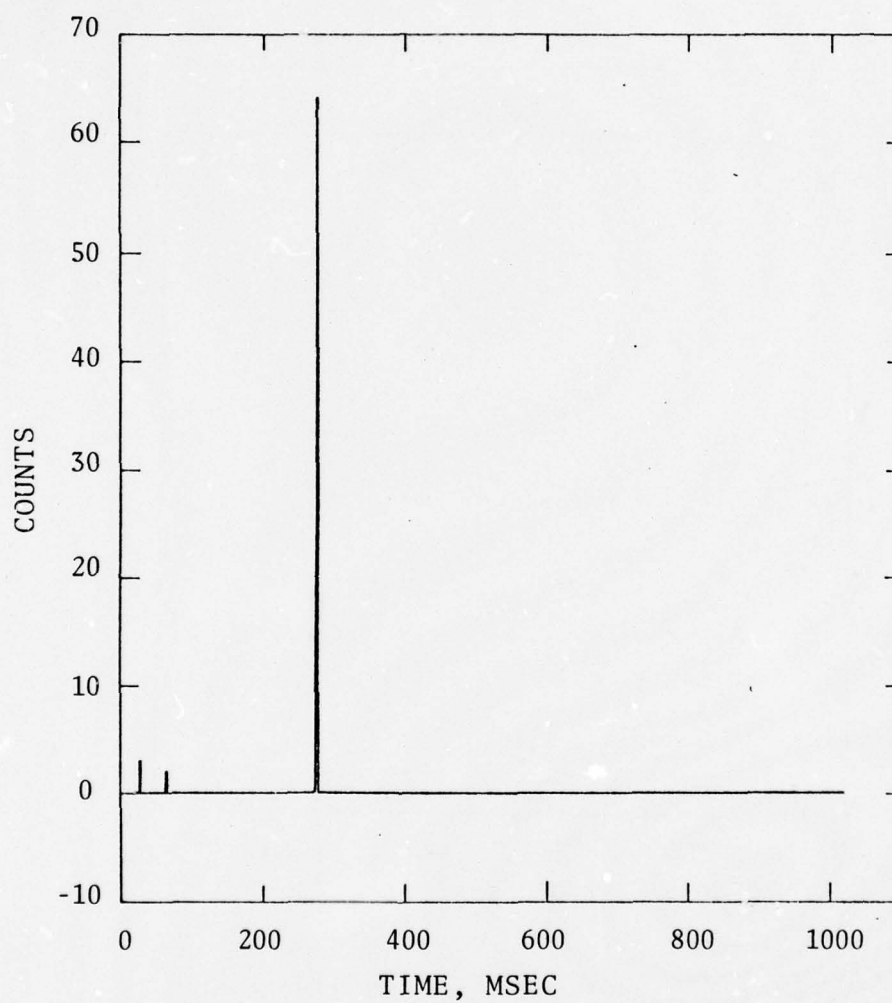


FIGURE 66. CAN C, CHANNEL 4A, MAY 16, 1976

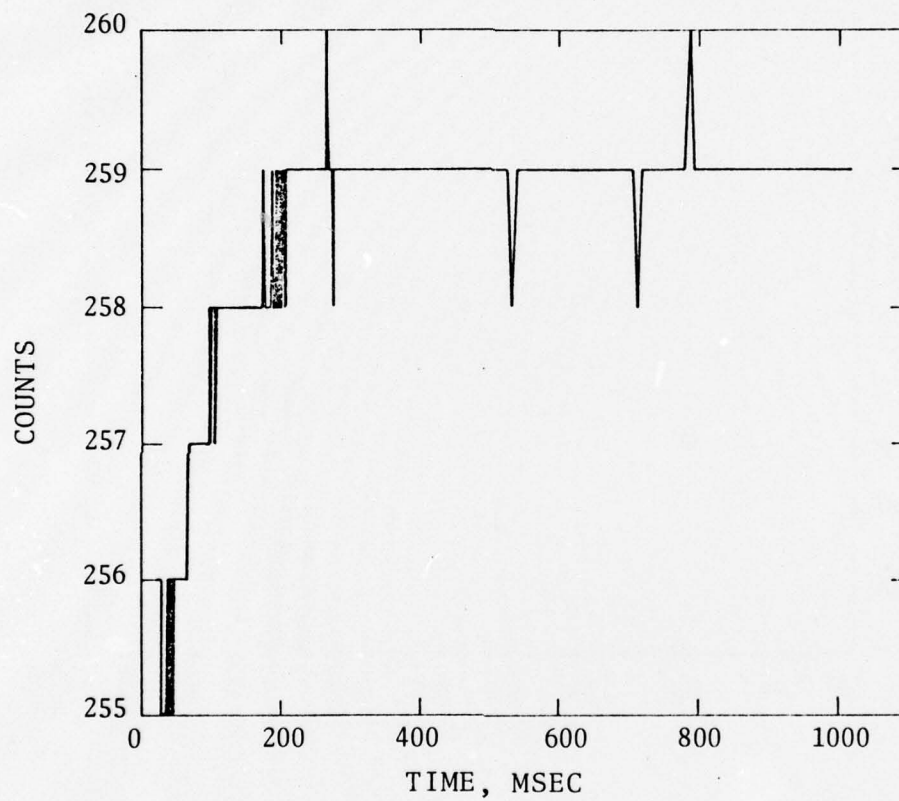


FIGURE 67. CAN C, CHANNEL 4B, MAY 16, 1976

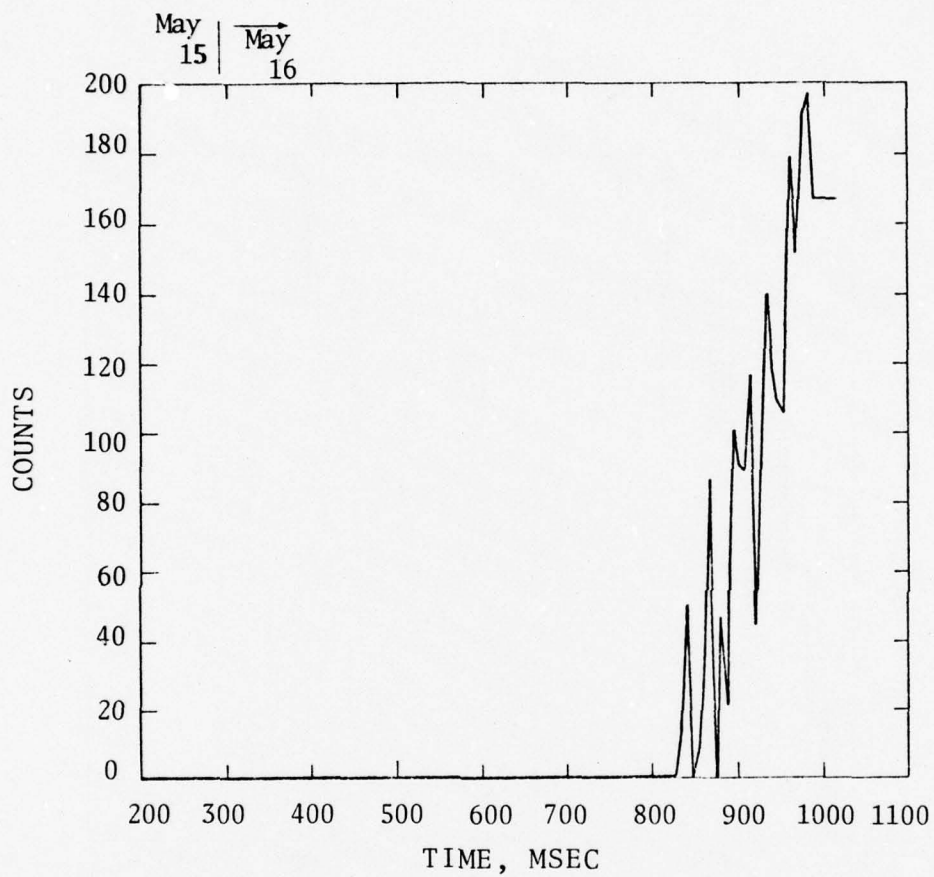


FIGURE 68. CAN C, CHANNEL 5A, MAY 15 & May 16, 1976

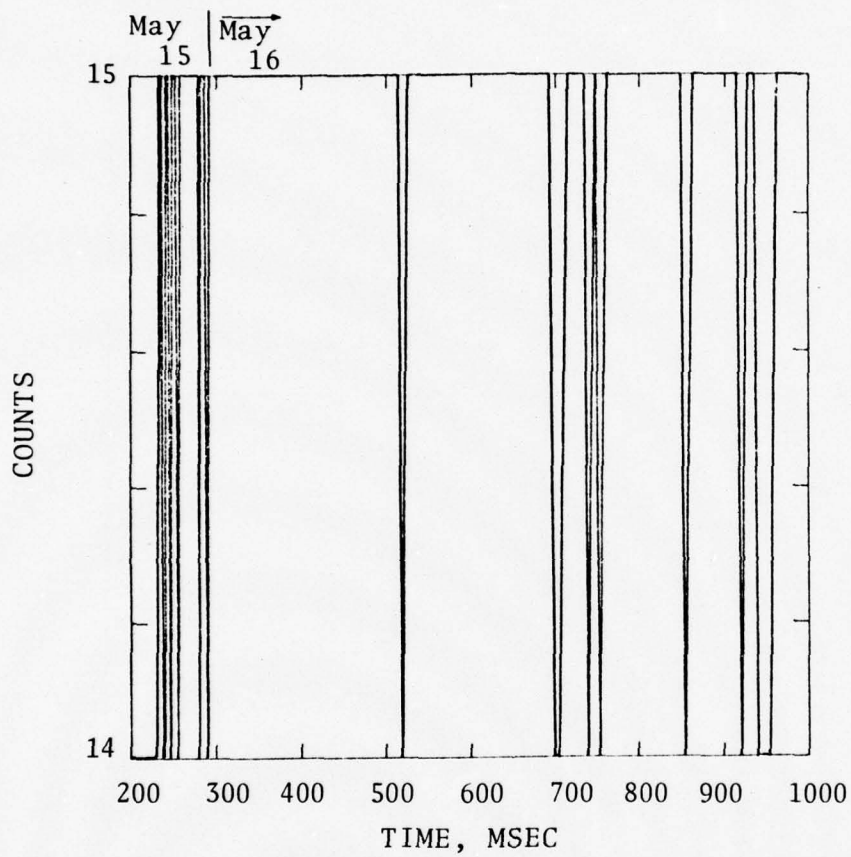


FIGURE 69. CAN C, CHANNEL 5B, MAY 15, & MAY 16, 1976

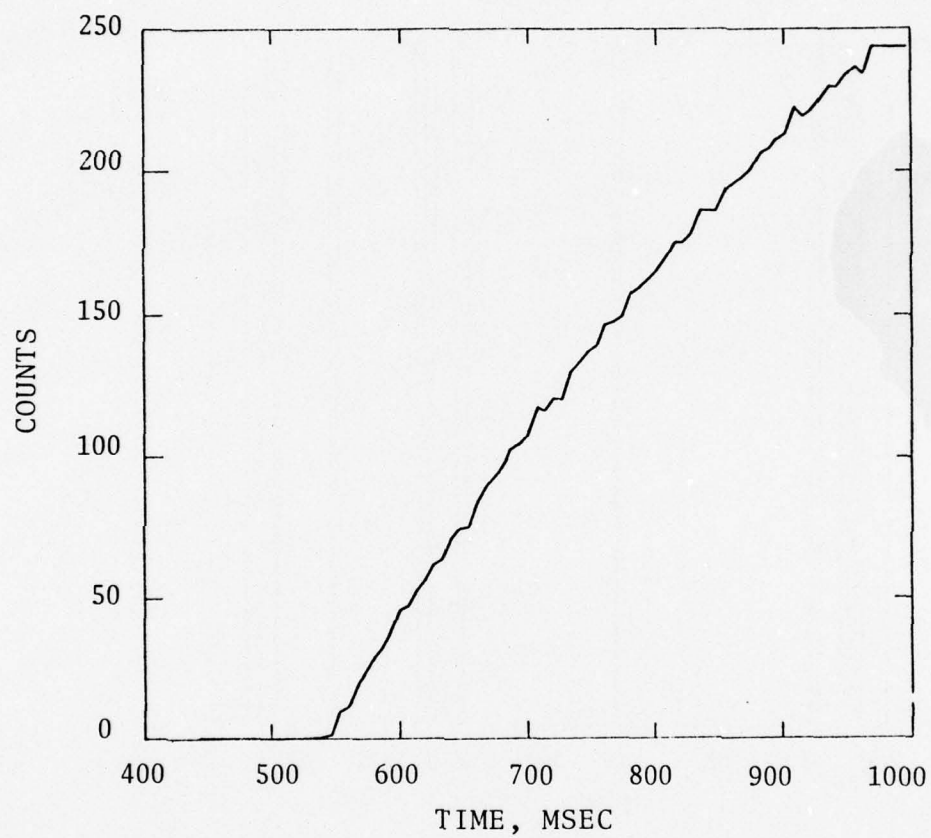


FIGURE 70. CAN C, CHANNEL 6A, MAY 15, 1976

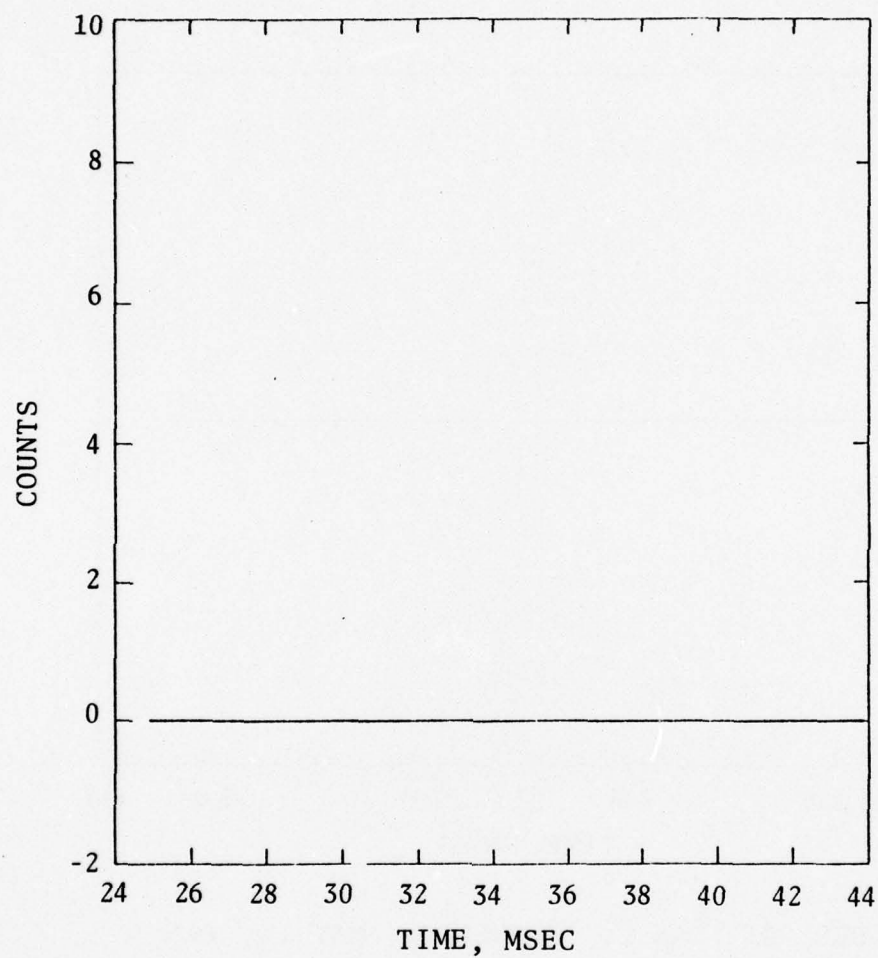


FIGURE 71. CAN C, CHANNEL 6A, MAY 16, 1976

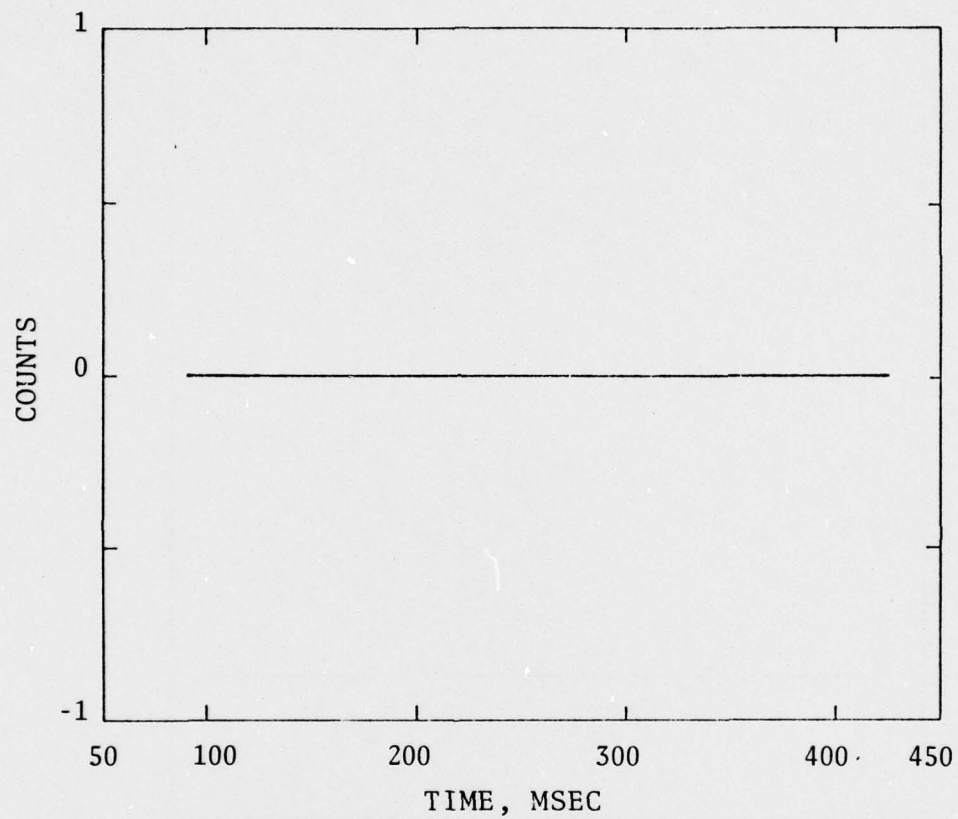


FIGURE 72. CAN C, CHANNEL 6A, MAY 16, 1976

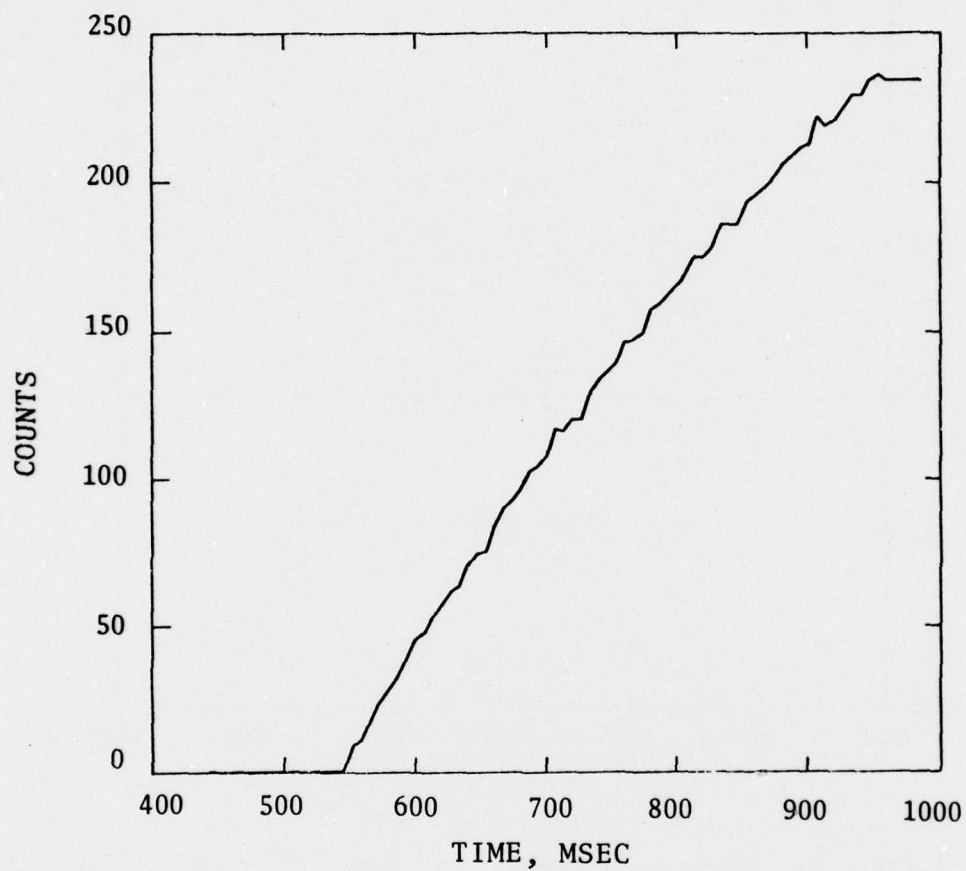


FIGURE 73. CAN C, CHANNEL 6A, JUNE 1976

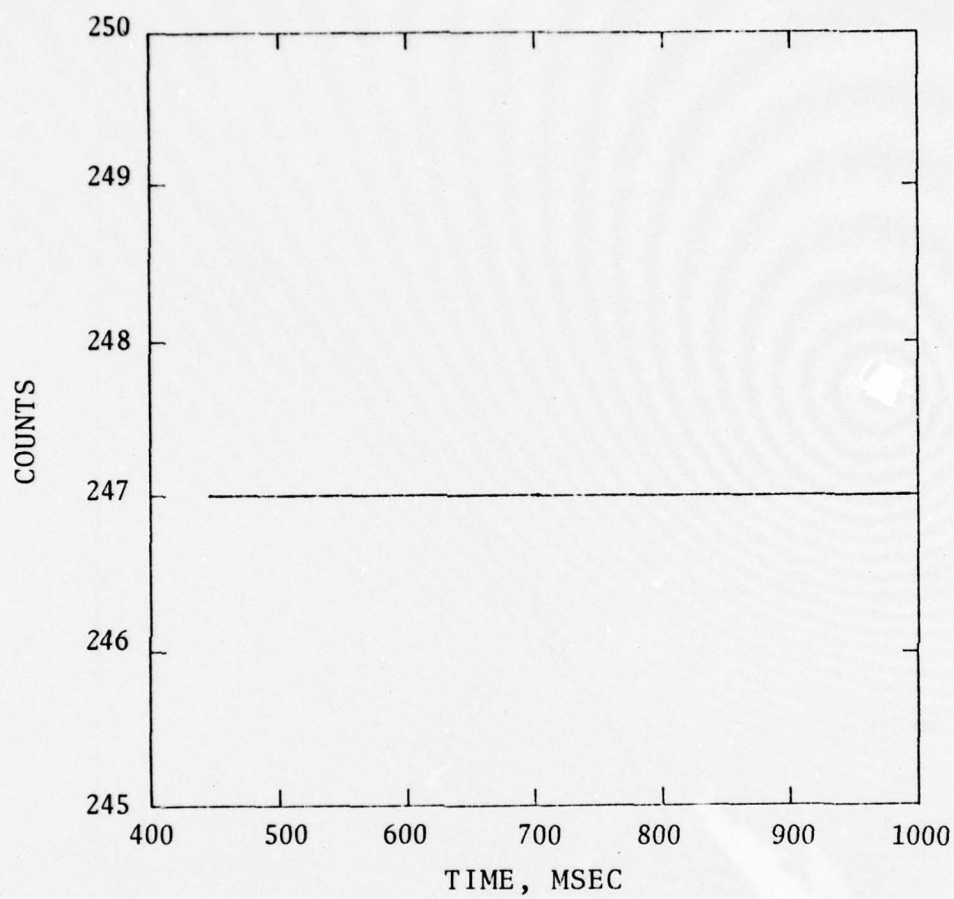


FIGURE 74. CAN C, CHANNEL 6B, MAY 15, 1976

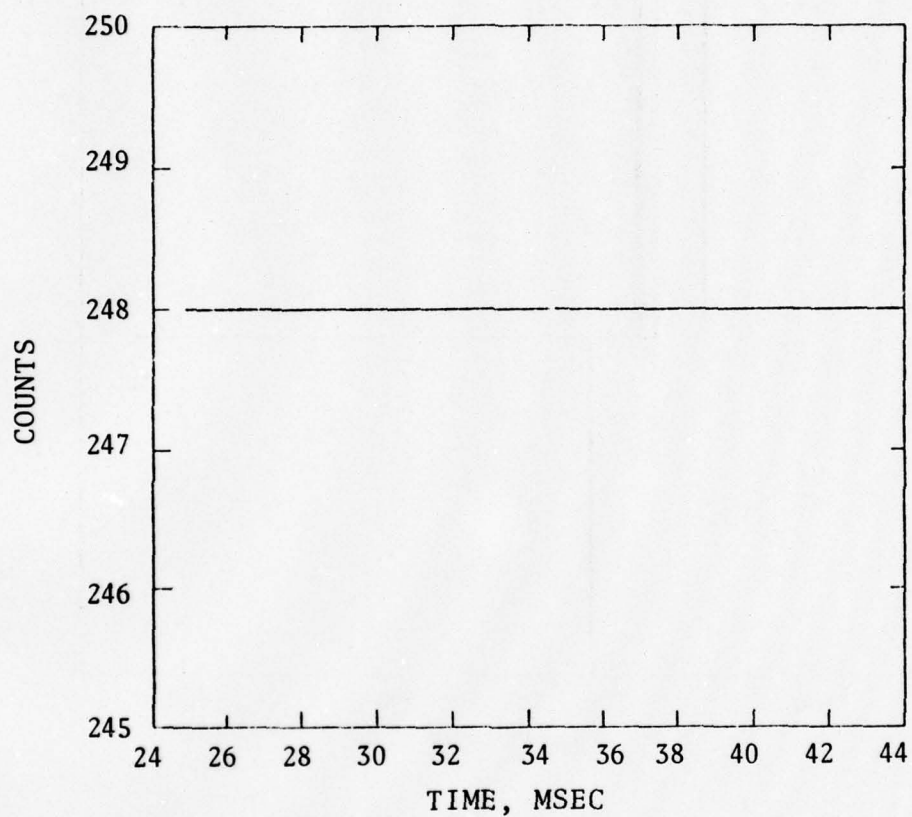


FIGURE 75. CAN C, CHANNEL 6B, MAY 16, 1976

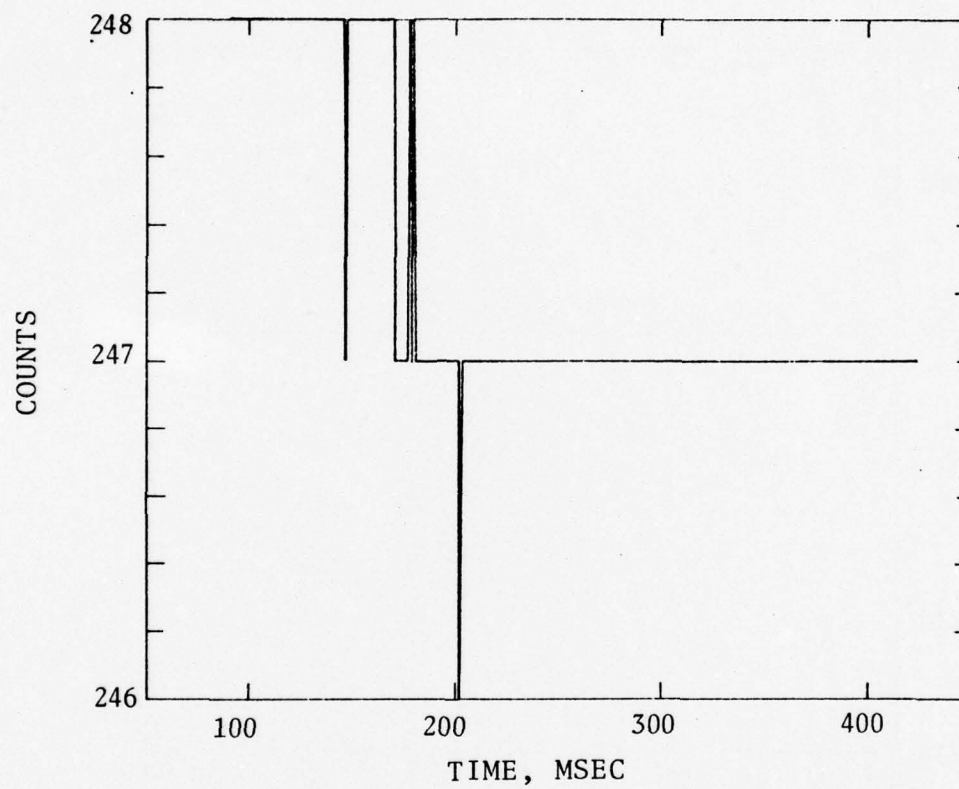


FIGURE 76. CAN C, CHANNEL 6B, MAY 16, 1976

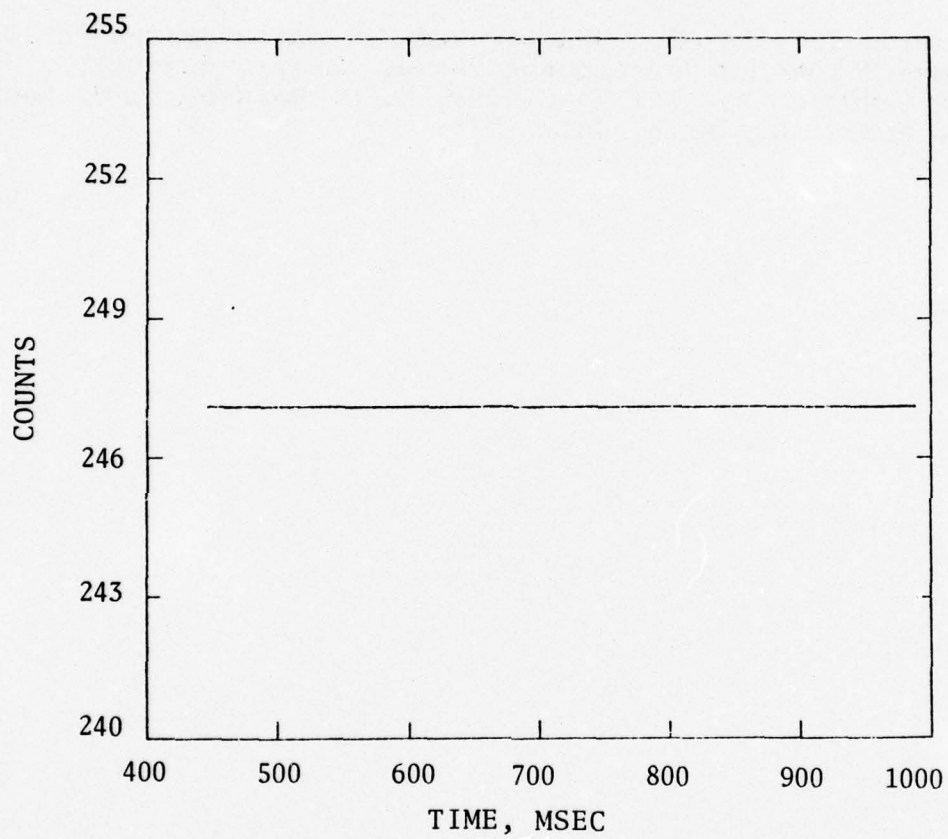


FIGURE 77. CAN C, CHANNEL 6B, JUNE 1976

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2. WES Final Report on MIGHTY EPIC, J. D. Day, unpublished.
3. Develco 937-750107, "Underground Telemetry System Development" (Design Development Phase, Interim Report), DNA Contract No. 001-74-C-0298, L. H. Rorden, L. C. Bacon, and R. L. Smith, July 1975.

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